Reclamation of Lands Disturbed by Mining

Proceedings of the Fourth Annual British Columbia Mine Reclamation Symposium

Vernon, B.C.
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BRITISH COLUMBIA MINISTRY OF
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THE MINING ASSOCIATION OF BRITISH COLUMBIA

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RECLAMATION OF LANDS DISTURBED BY MINING

PROCEEDINGS
of the
FOURTH ANNUAL BRITISH COLUMBIA MINE RECLAMATION SYMPOSIUM

Convened at
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Vernon, British Columbia
on
March 5, 6, and 7, 1980

Sponsored by

Technical and Research Committee on Reclamation
British Columbia Ministry of Energy, Mines and Petroleum Resources
and the
Mining Association of British Columbia

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EDITOR'S NOTE

These proceedings present the Symposium events in chronological order. Presented papers have been edited for stylistic consistency and typed. Time constraints prohibited final text proofreading by individual authors, consequently, the editorial staff accept responsibility for any errors.

Question and answer periods were tape recorded. In some instances recording quality was poor and some information was lost. Transcripts of these discussions when possible are given at the end of each presented paper within the proceedings. We apologize for any unwitting alterations in meaning.

OPENING REMARKS

by the

SYMPOSIUM CHAIRMAN

A. Milligan

Chairman

Technical and Research Committee

On Reclamation

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OPENING REMARKS

As the current Chairman of the Technical and Research Committee it is my pleasure to welcome you to the Fourth Annual British Columbia Mine Reclamation Symposium.

Reclamation has come a long way in the four years since the first of these Symposia. For example, we now know that many of those areas considered unreclaimable a few years ago have successfully been reclaimed to a high level of productivity by the use of proper species and cultural techniques. Furthermore, we have seen changes in the attitude of companies to the point where their responsibilities to environmental protection are now recognized as an integral part of the mining program.

The Committee feels that this encouraging attitude and the exchange of ideas is due, in part, to the work of the Annual Mine Reclamation Symposium. The intent of these annual gatherings has always been to foster the free exchange of information and experiences. Education has also been an essential element, so this year we have altered the Symposium format more to that of a short course and, hopefully, a learning experience.

The Technical and Research Committee is going to prepare a handbook of Reclamation which will outline the current state-of-the-art in British Columbia. Hopefully this Symposium will constitute the first step toward fulfilling this goal.

The outstanding success of this symposium is the result of considerable planning and background work by the members of the Committee. I would be remiss not to thank the Committee, particularly John Errington, the symposium convenar, for all their dedication and cooperation. To the delegates who presented papers, and to those who volunteered as chairpersons, thank you for your excellent contributions.

KEYNOTE ADDRESS

TO THE

FOURTH ANNUAL B.C. MINE RECLAMATION SYMPOSIUM

VERNON, B.C.

March 5, 1980

Integrated Natural Resource Management

by

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INTEGRATED NATURAL RESOURCE MANAGEMENT

Trying to find a definition for Integrated Natural Resource Management reminds me of the definition of a bachelor, as someone who comes to work from a different direction every morning.

Certainly, integrated resource management involves a considerable number of land and water users, each with their own needs and priorities. In addition to every other interest group, you who are involved in the extraction of minerals, fossil fuels, aggregates, etc., and the subsequent reclamation, have a significant role to play.

Integrated Natural Resource Management is a difficult and misunderstood art, involving understanding of the land - water ecosystem and a great deal of patience and interdisciplinary compromise, all moving in a wavy path toward more informed attention to interactions between the land and human activities.

Particularly in B.C., with its biogeoclimatic diversity, a great complexity of land use demands must be accommodated. These include, among many others:

Residential - whether single family or high density development in both rural and urban areas;

Transportations - namely highway alignments, railway location or corridors to alternate use areas;

Wildlife - increasingly must compete for key winter habitat, and is most often a loser-user in any economic trade-off;

Rural life-style pursuits - whether recreational small-holdings, hobby farms or rural residential, lakeside cottaging;

Community Watersheds - recognizing that our water supply areas must often be single-use oriented or near to it, to provide quality-quantity combinations acceptable from a health and demand point of view;

Forestry - those pursuits that provide for long-range wood production and its economic infrastructure;

Fisheries - concern, particularly with the anadromous fishes, that spawning habitats must be protected from the impact of other users of land and water;

Industrial - the pressure to manicure the landscape to whatever degree to provide opportunity to pursue the local tax base;

Agriculture - not only must it compete with other potential users of the land base but it also has conflicts within, such as the nursery trades at odds with the pork producers;

Mining - due to you people in the industry and government and with the small area of land involved as we see on T.V. - there obviously should be no land use or integration problems?;

Energy - whether flooding agricultural valleys or taking productive forest lands for transmission corridors, the result is conflict;

Recreational - intensive and extensive uses have various integration capabilities with other users;

- and the list goes on.

The question is, on a practical day-to-day basis, how do we feel with the competitors for that scarce resource "land" and how do we "integrate natural resource management"?

INTEGRATED NATURAL RESOURCE MANAGEMENT - WHAT IS IT?

Most of us support the philosophy of Integrated Natural Resource Management. Unfortunately, in practice, support only lasts as long as the land and its use is not affected or, in government, their agencies' interests are paramount and others can fit in wherever possible, if they don't interfere with the prime use thrust.

Compromises must be more than "have to" situations; "lip service" to integrated management is not good enough. Part of the problem is that most of us are trained in specific disciplines, with little opportunity for cross-disciplinary education. Then we are turned loose as resource managers with a specific piece of most often, single purpose legislation or single purpose company objectives and are told to make decisions on a well rounded, integrated basis. It's not possible - not without a great deal of practice.

Another part of the problem is that we can never really be sure we all mean the same thing when we talk of Integrated Natural Resource Management or, as in the following example, the term, multiple use. In a presentation to the Canadian Institute of Forestry Annual Meeting in Jasper, October, 1979, K.S. King, Director - General, International Council for Research in Agro-Forestry stated:

> "It used to be strongly argued (and there is still some validity in the argument for some places and for some types of combination) that multiple-use forestry is the answer to the conflicting demands for forest land. It is now recognized, however, that although it is possible to optimize the production of various packages of forest goods and services, the maximization of all the individual, single, goods and services which emanate from a forest cannot be attained. There has to be a trade-off. Use priorities have to be established.

> In the multiple-use package, there has to be a dominant use."

Thus, "poof" goes the long advertised U.S. Forest Service multiple-use motto, in real terms. I agree with K.S. King that there must be a dominant user. In my opinion, this is why I have always felt integrated resource management is the more acceptable term, implying, I hope, compromise and understanding of all managers and users.

For true integration we must weigh the environmental aspects of natural resource decision making with the economic ones. John Fraser, outgoing federal Minister of Environment, capsulized this well in response to a question reported in the January - March, '80 issue of Nature Canada.

The question was: "To what extent is our environmental quality dependent on our population and rate of economic development?"

Mr. Fraser replied:

> "Well, I see environment as an economic issue. If you ignore the environmental consequences of short-term economic developments you just pay a huge cost later. I've always said you've got to put the environmental considerations at the front end of the decision making process. I think it's fundamentally sound economics."

In my opinion, we miss this basic principle in many of our natural resource decisions. Eventually, unless we correct ourselves, we will be in a position of having no choice but to proceed on straight economic grounds. With the international historical legacy of littered ruins and battered landscapes left by former civilizations, you'd think we would know better.

INTEGRATED NATURAL RESOURCE MANAGEMENT - ARE WE PRACTISING IT?

No, unfortunately we are not. In many cases, Integrated Natural Resource Management has become synonymous with overregulation, slowed economic development, etc. Granted, any form of land use planning or management integration, whether urban or rural oriented, means a certain loss of personal, company, or agency freedom; but, hopefully, this is compensated for by a greater good for society as a whole. Undoubtedly, on occasion, we do get carried away with controls, especially when we fail to coordinate them with existing authorities, and we thus create bureaucratic monsters that alienate the public they are designed to serve.

There is the experience of the gentleman who owned a 40-acre parcel of land near the estuary of a major river on Vancouver Island. He wished to subdivide this parcel into two 20-acre lots along a paved access easement granted in 1940 to his neighbour. He discovered that all of the following agencies and their responsible legislation would have to be involved:

1. Municipal zoning was agricultural with a 30-acre minimum lot size, which meant he had to consider an application for rezoning.

2. Regional District regulations and by-laws had to be complied with.

3. As the land was in an Agricultural Land Reserve he was subject to the Agricultural Land Commission Act; consequently he would need to submit an application under that legislation.

4. Ministry of Highways would require access to lands beyond, as well as access to the river.

5. Most of the property was on a floodplain, therefore Water Resources regulations would also apply.

6. Public Health were concerned about effluent disposal due to high water tables.

7. The adjacent river was navigable water and under Federal jurisdiction, therefore he had to consider that regulation.

8. The river was a salmon spawning stream and therefore subject to the Environment Canada's Fisheries Act.

9. National Harbour Board's legislation had some influence, because of marine frontage.

10. A historical trail, unidentified but recorded on the property title, traversed the property.

11. Finally, there were Land Registry Act problems, as the marine foreshore property boundary had not been accurately identified.

This was all very frustrating to the individual, to say the least. On the other side, line agencies of government, when confronted with all these referrals and forced to answer to political criticism of time spent on such attempts at integrated natural resource management, too often revert to single use cocoons, forgetting the other users, except when open confrontation necessitates attention to their presence.

As a solution to this problem, some propose grouping all these interests under one regulatory umbrella. Unfortunately, this "one stop shopping centre" approach to all regulatory approvals leaves much to be desired.

THE FUTURE

Where do we go from here? At the risk of oversimplifying the situation, I will leave you with a few of my basic directions:

1. Government legislation affects almost every facet of natural resource management. Much is at stake for all involved: the quality of life for some, life itself for others. Someone, and that means Government, must take the responsibility for the shape and tone of laws and regulations that encourage integration including, what is encompassed, what is expected, what is prescribed and what is tolerable.

2. Integration efforts must recognize provincial diversity, and I feel that decentralization of natural resource agencies provincially is a step forward. However, legislation, regulation and staffing commitments must follow if it is going to be a significant integrative force. Recently, there have been indications that single-use oriented decision making is moving to the forefront again.

3. We are still in need of an overall provincial land use strategy. What are the provincial commitments to food production, wood production, recreational resources, wildlife populations, and mining? The usable land resource is limited and a provincial policy is still lacking.

4. Some of the extant integrating mechanisms need encouragement and further support:

    a. The new energy policy refers to an improved public involvement process - it should be encouraged.

    b. Coordinated Resource Management Plan process on rangelands needs careful examination and could be viewed as a base for other coordinated efforts.

    c. The E.L.U.C. Secretariat needs support as an integration mechanism. There is also a need for regional coordination support staff.

d. Guidelines, such as the Coal Development Guidelines, need amendment to regulation status, to ensure that integration is undertaken.

e. There is some evidence that we are working toward integrated water basin planning - it should be encouraged.

Fundamental, of course, is the need for integrated resource management principles and policies. Every land or resource use that exists is in some way, directly or indirectly, associated with another use. And, hand-in-hand with these principles and policies there must be guidelines, regulations and fair-to-all enforcement. Like Integrated Natural Resource Management itself, this is a package deal and none can exist effectively without the other. To quote, from an unknown source:

> "The society which scorns excellence in plumbing because plumbing is a humble activity and tolerates shoddiness in philosophy because it is an exalted activity will have neither good plumbing nor good philosophy. Neither its pipes nor its theories will hold water."

SOILS AND FERTILIZERS

Chairman of the Afternoon Session
Wednesday, March 5, 1980

R. Hawes
British Columbia Research

PROPERTIES OF SOILS AND THEIR IMPLICATIONS IN THE RECLAMATION OF LANDS DISTURBED BY MINING

by

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PROPERTIES OF SOILS AND THEIR IMPLICATIONS IN THE RECLAMATION OF LANDS DISTURBED BY MINING

INTRODUCTION

Traditional definitions of soil often involve the phrase "natural medium for the growth of land plants". The differing properties of soils are attributed to the integrated effect of climate and biological mechanisms acting upon geologic material as conditioned by relief over time. In the Canadian System of Soil Classification (1978) naturally occurring soils include those disturbed by activities such as cultivation and logging but do not include man-displaced materials such as gravel dumps and mine spoils.

Natural soil extends from the surface to the depth at which soil forming processes can no longer be detected; therefore, a "non-soil" underlies unconsolidated material which has not undergone pedogenic processes. A more encompassing definition is given in the American System of Soil Classification "Soil Taxonomy" (1975), which states: "Soil...is the collection of natural bodies on the earth's surface, in places modified or even made by man, of earthy materials containing living matter and supporting or capable of supporting plants out of doors." This definition includes drastically disturbed materials such as mine waste deposits.

I prefer this latter wider definition; however, in this paper soil includes that which occurs naturally as defined by the Canadian System and also the deeper surficial deposits not affected by soil forming processes. I believe that these deeper "non-soil" deposits often provide the most economic medium for reclaiming lands disturbed by mining.

My literature search indicated that research has been focused on the properties of mine waste materials and on the opportunities for reclaiming these lands using soil amendments and various leaching processes. Much less information is available concerning the use of naturally occurring soil as a source of cover to aid the reclamation process. It seems logical to me to use naturally occurring soil instead of trying to create a medium for plant growth from mine wastes in a fraction of the time it took Mother Nature to create soil. Recent legislation in some areas of North America stipulates that naturally occurring soil material in the area to be mined must be moved and stored for reclamation of the mine site. The limited amount of information concerning this innovation suggests that positive results were obtained, however, two areas of concern expressed were cost effectiveness and contamination problems at the soil-spoil interface.

SOIL MAPPING

A recent paper in Reclamation of Drastically Disturbed Lands states: "There should be an engineering dictum that advance planning is essential to success in major disturbance activities. It is inconceivable that a responsible engineer would start building a highway, an urban mall or a surface mine without some appraisal of the rock and soil to be disturbed or used" (Smith and Sobek, 1978). Accordingly, for any mining project an up-to-date soil survey at a suitable level of detail should be incorporated into the planning process at the earliest stage possible. This soil survey will provide base data for the reclamation of disturbed lands and for ancillary developments such as energy and transportation corridors, plant sites and housing developments.

LEVEL OF DETAIL

Soil surveys can be carried out at three levels of intensity. Reconnaissance soil surveys are regional in scope and the mapping scale is generally 1:50,000 (2 cm = 1 kilometre) or smaller. Semi-detailed surveys are often still regional but can be effective during the early planning stages even for area specific purposes. The scale of semi-detailed surveys generally ranges from 1:20,000 to 1:40,000 (5 cm = 1 kilometre to 2.5 cm = 1 kilometre). Detailed soil surveys are used for site specific planning and are generally 1:10,000 (10 cm = 1 kilometre) or larger. The level of site inspection undertaken during these different soil surveys increases proportionately to the scale of the survey.

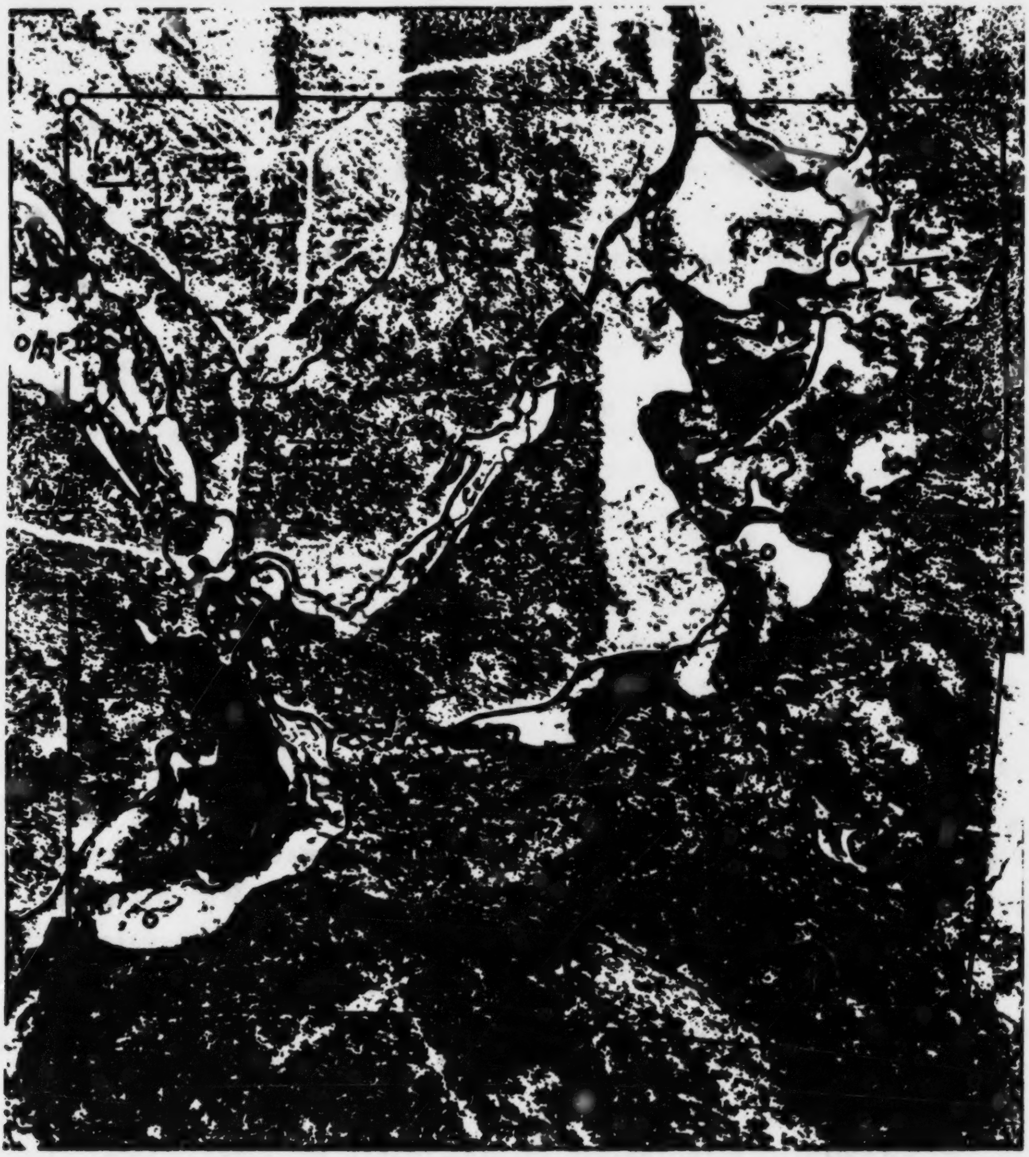
Selection of an appropriate mapping scale and intensity of survey depends on the purposes of the survey. Generally speaking for such things as corridor selection for linear developments like road location, the map scale should be at least 1:25,000. For delineating bodies of soil suited to stockpiling for reclamation, a mapping scale of at least 1:10,000 is necessary. As a general guide one should keep in mind the area represented by a 1 cm square at a given mapping scale. At 1:50,000 a 1 cm square area covers 25 hectares and at 1:10,000 1 cm square covers 1 hectare.

MAPPING METHODOLOGY

The first step in creating a soil map is to obtain the most recent aerial photographs available at a scale which approximates that of the maps to be produced. The aerial photographs are pre-typed through stereoscopic interpretation and by using any information on the geology and soils of the area. Pre-typing generally involves the delineation of the preliminary mapping units according to landforms and materials. The terrain classification system of the E.L.U.C. secretariat in 1976 can be used to pre-type aerial photos of B.C. landscapes. Figure 1 shows an aerial photograph at a scale of 1:20,000 which has been pre-typed and classified using the terrain classification system prior to field mapping. Note the use of wing points and correlation to the flightlines above and below. These are useful in the field and are time savers. Preliminary site locations are laid out according to the

Figure 1

AERIAL PHOTOGRAPH (SCALE 1:20,000), PRE-TYPED AND CLASSIFIED



mapping unit delineations on the photograph so as to arrive at representative sites at a reasonable level of field checking.

The field program includes site location using the pre-typed photographs and whatever means of transportation is necessary. Site classification involves the description of environmental features including the terrain, vegetation and soil. The Resource Analysis Branch of the Ministry of the Environment has compiled complete site, soil profile and vegetation description forms in their Manual for Describing Ecosystems in the Field (1980, in print).

Soil pit excavation is a topic very dear to my heart considering all the layers of skin that I have removed over the years trying to bang down a soil pit in very unfavourable conditions. During most of my recent survey work attempts have been made to use a regular backhoe where access allows, or a climbing backhoe in more difficult terrain. It saves your hands and time, moreover, the end product gives much more detail as to the variability of the soil profile and its changes with depth. A tractor and power-auger is also adaptable where the terrain and soils are suitable. The amount of information obtainable using the power-auger is not as extensive as that using the backhoe because of the small pits and mixing of materials, however it is a useful method for checking variability of deposits. Considering that access to most of the potential mine areas in the province may limit excavation to the hand method, it is essential that sufficient manpower and time is made available to excavate pits of adequate size and depth so that soil variability with depth can be ascertained.

Soil classification should be in accordance with the Canadian System of Soil Classification, 1978. Although much of the classification is Greek to most non-soils people, it is important information to the pedologist who must make sound interpretations.

The selected mapping base depends on the preference of the users. Most engineers like planimetric maps with contours, whereas, many soils people choose a controlled photo mosaic or orthophoto compiled from the aerial photography. Mapping legends will depend on the users needs. For the base soil map, I prefer a fairly detailed and comprehensive legend followed by the preparation of derivative maps which present suitability interpretations for various uses.

No soil survey is complete without a sampling program and laboratory analyses. The sampling program design is important because samples must be representative of the various soil types in the project area. The analyses should meet the needs and objectives of the survey. The pedology laboratory of the Department of Soil Science at U.B.C. has compiled a Methods Manual (1977) applicable to the B.C. situation. This laboratory as well as other private and governmental labs are able to carry out the analyses.

SOIL PROPERTIES

Soils possess unique physical and chemical characteristics which influence their behaviour under varying conditions. Soils are generally separated into mineral and organic categories. The following discussion is general in scope and addresses only those soil properties important in mine waste reclamation.

MINERAL SOILS

Mineral soils contain less than 30% organic matter by weight.

Physical Properties

These soil properties affect both the engineering behaviour of the material as well as plant growth. The physical characteristics significant to the use of soils in mine waste reclamation are discussed under two headings: "Inherent Characteristics" and "Behavioural Characteristics".

Inherent Characteristics

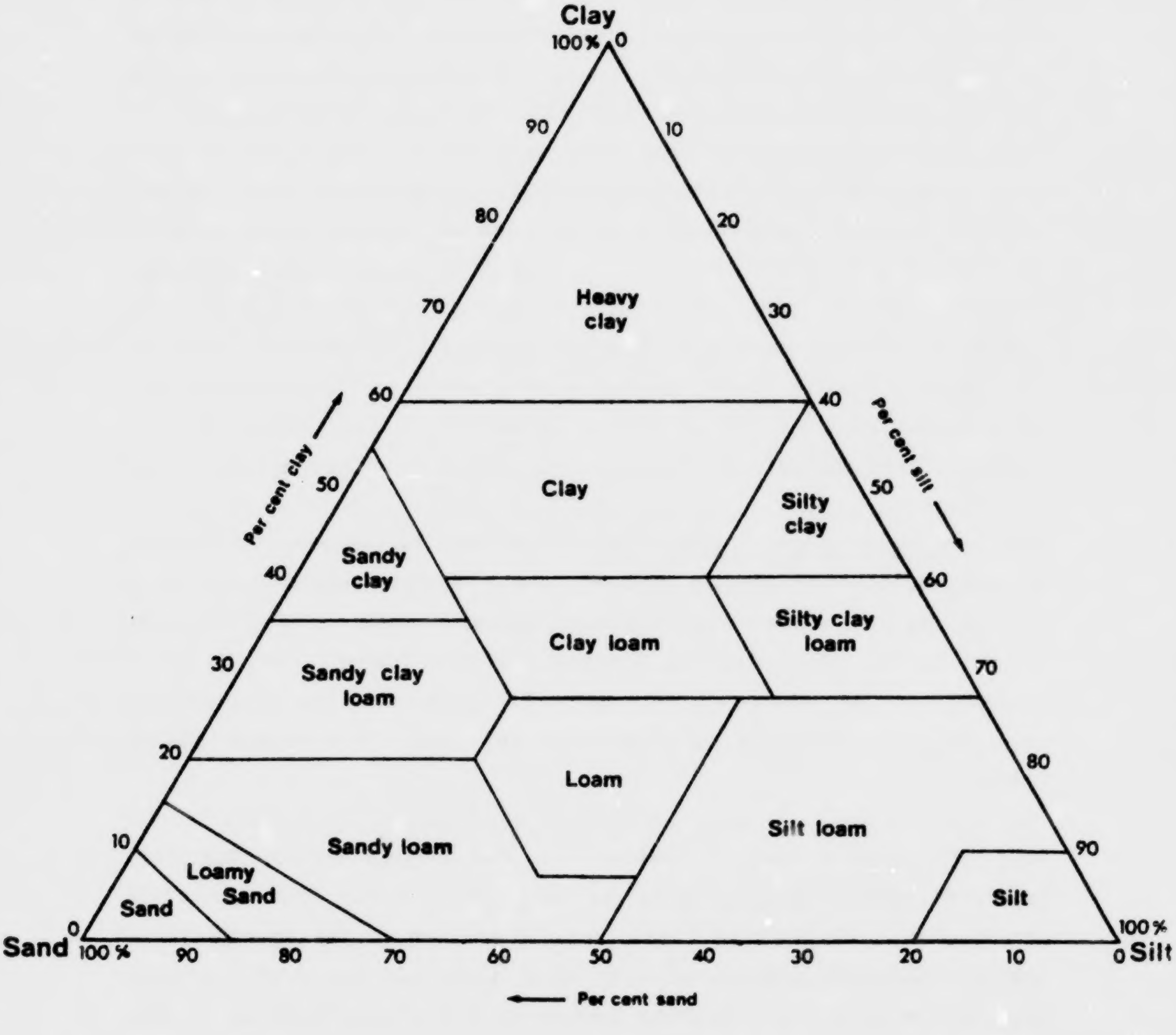
Particle Size Distribution - This refers to the grain size distribution of the whole soil including the coarse fragments. The Canadian System of Soil Classification (1978) uses the term texture to refer to the fine earth fraction (less than 2 mm) of the soil. The relative percentages of sand, silt and clay comprising the fine earth fraction are used to determine soil texture. Figure 2 depicts a soil texture triangle and shows the relative proportions of sand, silt and clay in the various textural groupings. Using this system, soil textural classification is generally modified by such terms as gravelly or cobbly to indicate the coarse fragment content. For mapping soils at the family and series level the Canadian System establishes 11 particle size classes on the basis of coarse fragment size and content as well as on textural analysis.

Bulk Density or Volume Weight - This is defined as the mass of dry soil per unit bulk volume and is probably the most important single factor influencing the engineering parameters of soil (USDA, SCS, 1975). In general terms, soil strength increases with increased density while permeability and compressibility generally decrease. The bulk density of a soil is increased by compaction and consolidation under heavy loads.

Soil Structure - This is defined as the arrangement of the soil separates into secondary units called peds. These peds are often arranged in a distinctive characteristic pattern in the soil profile. Soil ped classification is based on size, shape and degree of distinctness according to the Canadian System of Soil Classification (1978). Soil structure is indicative of both physical and chemical characteristics of a soil and influences management practices in varying degrees.

Figure 2

Proportions of Soil Separates in Various Soil Textural Classes[1)]



[1)] SOIL TEXTURAL CLASSES ARE GROUPED AS FOLLOWS:

Coarse textured - sand, loamy sand, sandy loam.
Medium textured - very fine sandy loam, loam, silt loam, silt
Fine textured - sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, clay.

SEPARATE	DIAMETER (mm)
Sand	0.05 - 2.0
Silt	0.002 - 0.05
Clay	<0.002

Behavioural Characteristics

Many soil behavioural characteristics are recognized in the engineering field manual of the USDA, SCS, (1975). Only those characteristics considered most important to mine reclamation are described below.

Plasticity - This is the most important attribute of fine grained soils in terms of engineering behaviour. Soils with a high plasticity generally have a higher cohesion and resistance to surface erosion, piping, and cracking than soils with lower plasticity. The plastic limit is the water content corresponding to an arbitrary limit between the plastic and semi-solid states of consistency of the soil. This limit is determined by the water content at which a soil will just begin to crumble when rolled into a thread of approximately 1/8 inch in diameter.

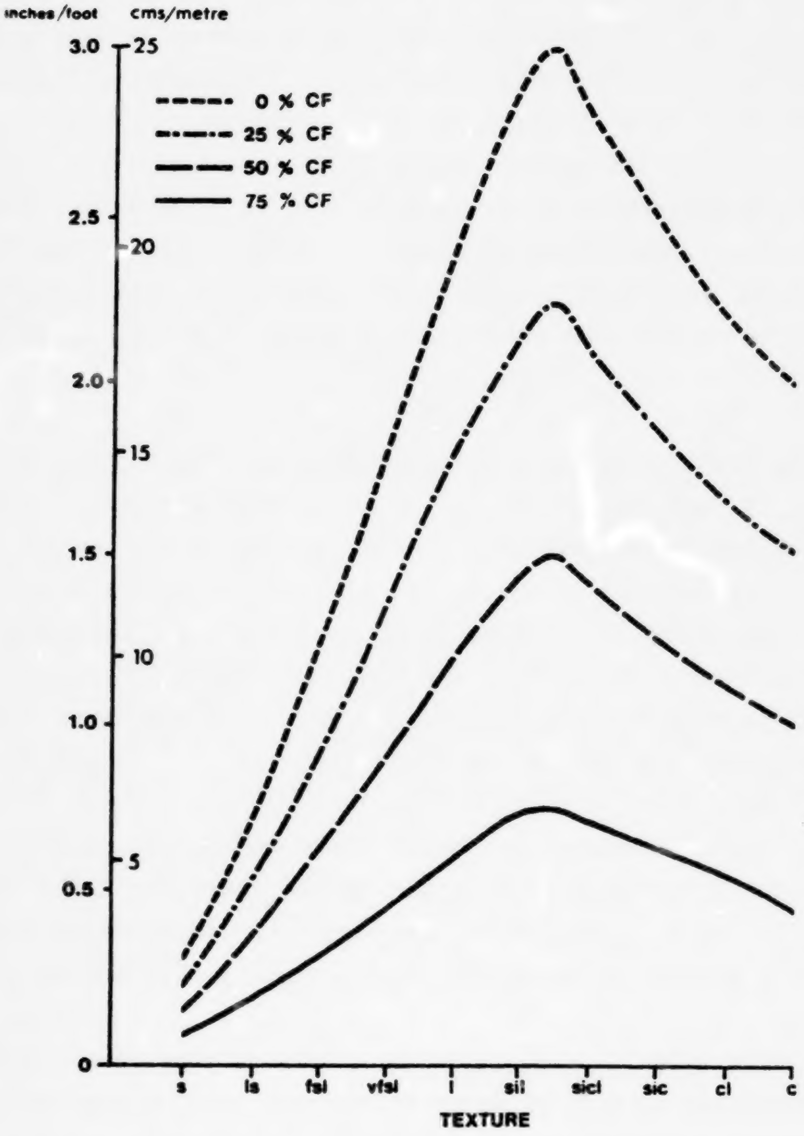
Liquid Limit - This is the second most important behavioral characteristic of fine grained soils. It is defined as the water content corresponding to an arbitrary limit between the liquid and plastic states of consistency of the soil. It is determined by the water content at which a pat of soil cut by a groove of standard dimensions will flow together for a distance of 1/2 inch under the impact of 25 blows in a standard liquid limit apparatus. Both clay and silty materials may have either high or low liquid limits.

The difference between the liquid limit and the plastic limit is termed the plasticity index, and it defines the range over which the soil exhibits plastic properties. The plasticity index is used to classify soils according to the unified system used by soil engineers.

Available Water Storage Capacity - This is considered by most to represent that portion of water in the soil readily available for plant use. It is defined as the difference between the amount of water in the soil at field capacity and that in the soil at the permanent wilting point of most plants. Figure 3 gives an approximation of the

Figure 3

Approximation of Available Water Storage Capacity



s	sandy	**sil**	silty loam
ls	loamy sand	**sicl**	silty clay loam
fsl	fine sandy loam	**sic**	silty clay
vfsl	very fine sandy loam	**cl**	clay loam
l	loam	**c**	clay

available water storage capacity of soils according to texture and coarse fragment content. The important inference here is that medium textured soils (loam to silt loam) have the highest available water storage capacity, whereas, for fine textured soils (silty clay loam to clay), the available water storage capacity decreases with the degree of fineness. Similarly, water storage capacity decreases with increasing coarse fragment (CF) content.

Permeability - This is a soil property that allows the transmission of water and air. Permeability is measured as the rate at which water is transmitted under saturated conditions and can be equated with saturated hydraulic conductivity. Permeability can be estimated from soil characteristics observed in the field such as texture, structure and soil pores. Generally, permeability increases as grain size increases and decreases as density increases.

Consistence - This indicates the resistance of the soil peds to deformation and is a factor of the degree of cohesion of the soil particles. Consistence is described according to the moisture content of the soil under dry, moist and wet conditions. Consistence influences the ease of excavation as well as handling and management of a disturbed soil.

Erosion - This is defined as the wearing away of the soil surface by water, wind, ice and other processes. Soil susceptibility to both surface and internal erosion (piping) is critical to the reclamation process. Generally, soils with a high susceptibility to surface erosion have a high susceptibility to internal piping. This is in contrast to low susceptibility soils which are generally more plastic and not as susceptible to surface or internal erosion.

Many other important behavioural characteristics of concern to soil engineers should be considered in the use of soils for mine waste reclamation. Basically geotechnical, they include compressibility, shrink-swell and bearing capacity.

Chemical Properties

These soil characteristics affect both the engineering behaviour and plant growth. The following briefly discusses some of the more important chemical characteristics of mineral soils.

Reaction - This is defined as the degree of acidity or alkalinity of the soil and is expressed in terms of pH. Descriptive classes for pH range from extremely acid at pH's less than 4.5 to very strongly alkaline at pH's greater than 9. Reaction influences soil corrosivity and is therefore important in engineering considerations and also strongly influences plant growth. Plants generally have a narrow range of pH tolerance although some plant species are pH specific.

Salinity - This is defined as the amount of soluble salts in the soil and is expressed in terms of electrical conductivity of the soil saturation extract in mmhos per cm at 25° centigrade. Salinity affects the suitability of a soil for plant production as well as stability for construction purposes and corrosivity to metals and concrete.

Cation Exchange Capacity (CEC) - This is defined as the total amount of exchangeable cations that a soil can absorb and is expressed in milliequivalents per 100 grams of soil. The cation exchange capacity of a soil is an index of its inherent nutrient holding capacity and is markedly influenced by organic matter content, the amounts and kinds of clay present, and, to a more limited extent, the pH of the soil. Generally, finer textured soils have a higher cation exchange capacity than coarse textured soils and, within a particular textural class, organic matter content and the amount and kind of clay present influences the CEC.

Fertility Status

To ensure plant growth, an adequate supply of nutrients must be maintained in the soil medium. For reclamation purposes, the physical and chemical characteristics of soils discussed previously are adequate for the assessment of nutrient holding capacity. However, for successful plant growth, the availability and proportion of plant nutrients must be known for proper maintenance of the reclaimed area.

Plant Nutrients - Plants obtain sixteen essential elements from the soil, three of which are commonly deficient and are therefore referred to as primary nutrients. These are nitrogen, phosphorus and potassium. Calcium, magnesium and sulphur are secondary nutrients which are less often deficient in soils. Plant growth in soil will be retarded if any of these elements are absent, insufficient or unbalanced with the supply of other nutrients. These elements are commonly supplied in the form of commercial fertilizers.

Micro-nutrients or trace elements are those taken up by the plants in very small quantities. These include iron, manganese, copper, zinc, boron, molybdenum, chlorine and cobalt. They are just as essential to plant growth as the other nutrients, but are required in much smaller amounts. Micro-nutrient uptake is often a problem in coarse textured soils, organic soils or soils having extreme reaction.

Toxicities - Many of the micro-elements in excessive amounts may be toxic to plants. As an example, excessive copper has been shown to depress the uptake of iron by plants, which lead to symptoms of iron deficiency (Tisdale and Nelson, 1969). In B.C. soils other toxicities may arise due to relatively high levels of manganese, molybdenum, boron and selenium. Soil analysis should be carried out prior to the use of any material in mine reclamation. The analysis should include trace element detection particularly for any element expected to occur in relatively high amounts, based on knowledge of the regional geology and soil types.

ORGANIC SOILS

These soils are recognized at the order level prescribed in the Canadian System of Soil Classification. They are described as soils derived dominantly from organic deposits and by definition contain more than 30% organic matter by weight. Most of the soils commonly referred to as peat, muck or bogs are included in the organic order. Such soils are usually water saturated during most of the year, occur in wet depressional areas, and are derived from hydrophytic vegetation. However there are exceptions, some organic soils comprise organic matter accumulated on steeply sloping, well drained, forested sites.

Under the Canadian System of Soil Classification organic soils are classified according to their degree of decomposition. For example, fibrisols are composed dominantly of relatively undecomposed fibric materials, mesisols are dominantly semi-decomposed mesic material; and humisols are dominantly well humified broken down organic materials.

Organic soils often make poor construction materials, and they require specific handling if used in the reclamation process. I wish to emphasize organic soils because of the tremendous number and variety of such deposits throughout B.C., particularly in mining areas. There is tremendous potential for utilizing these deposits as a soil amendment during reclamation, to increase the soil's cation exchange capacity and available moisture, to lower bulk density and help maintain desirable pH levels.

SOIL SUITABILITY FOR RECLAMATION

The suitability of soil for reclamation is determined from soil survey and analytical data. This determination should be carried out not only for soil in the area of the mine site, perhaps the most important area, but also for the surrounding environs. The approach described follows the Guide for Interpreting Engineering Uses of Soils USDA, SCS (1971).

This document contains a guide table for establishing suitability ratings of soils to be used as topsoil.

In many parts of North America, particularly in the Great Plains area, this type of assessment would be adequate for determining whether or not a surface soil should be stockpiled for use during the reclamation. Most of the Prairies are relatively flat, have fairly homogeneous soils belonging to the Chernozemic (grassland) order, and have fairly deep topsoil layers composed essentially of mineral materials complexed with organic matter. However, in many B.C. mining areas, topsoil does not exist or, if it does, it is very shallow in depth and limited in extent. There are not many B.C. locations that I can think of where it would be feasible, especially in the economic sense, to strip and conserve true topsoil material. Undoubtedly there are exceptions such as in parts of the Okanagan where a fairly extensive cover of Chernozemic soils exhibit some deep Ah horizons suitable for stockpiling.

The approach that should be taken is to assess the surficial material, including the surface and subsurface unconsolidated soil material, to determine its usefulness for the reclamation of mine waste. For a specific location it might be feasible to stockpile topsoil; but for other locations where that is not feasible, it may be worthwhile to stockpile surficial deposits that have the characteristics of a potentially suitable cover material.

Table 1 is a modification of the topsoil suitability guide referred to earlier. It represents an attempt to identify the various soil characteristics which affect the use of the material for mine waste reclamation and to establish limits as to the degree of soil suitability for use as a cover material. This table is only a general guide and may or may not be applicable in specific mining areas. It certainly could be much more elaborate. For example, the textural classes used could be replaced by unified soil classes and other behavioural characteristics could be identified according to their type

Table 1

SUITABILITY RATINGS OF SOILS AS SOURCES OF COVER MATERIAL FOR MINE WASTE RECLAMATION

ITEM AFFECTING USE	DEGREE OF SOIL SUITABILITY		
	GOOD	FAIR	POOR
Texture	SL L SiL SC L	SiCL. CL SC LS	SiC C S peat muck
Moist Consistence	very friable	loose, firm	very firm; extremly firm
Coarse Fragment Content	<15%	15-35%	>35%
Stoniness Class	non-stony, slightly stony (classes 0,1)	moderately to very stony (classes 2,3)	exceedingly to excessively stony (classes 4,5)
Drainage Class	not limiting if better than poorly drained		poorly drained and very poorly drained
Thickness of Material	>100 cm	50-100 cm	<50 cm
Soluble Salts (Electrical conductivity)	<4 mmhos/cm	4-8 mmhos/cm	>8 mmhos/cm
Reaction Class (pH in water)	slightly acid to mildly alkaline (6-8)	medium acid (5.5-6) mildly alkaline (7.5-8)	strongly to very strongly acid (4.5-5.5) moderately alkaline to strongly alkaline (8-9)
Cation Exchange Capacity (meg./100 gm soil)	>25	15-25	<15

and degree of limitation. Similarly, other factors such as available water holding capacity could be included. It should be noted that the table gives only estimates of the degree of soil suitability. Although it would be preferable to have a "good" soil material available, it may be that in some cases only soils rated "poor" in the table are available. Nevertheless, they are still suitable for reclamation, and despite their low degree of suitability, various soil amendments and management practices could be used to alleviate their limitations.

Figure 4 represents a portion of a soil map compiled from the aerial photograph shown in Figure 1. This area was mapped at a scale of 1:20,000 and I have used it as an example of the type of information that might be presented from a soil survey during mine site planning. Seven mapping units and two sub-components were established. Table 2 shows a simplified legend that might accompany this type of map and indicates the characteristics of the mapping units and rates the soil in terms of its suitability as a source of cover material.

Based on adequate soil survey information, an assessment of the surficial material at the mine site as a source of suitable cover material for mine waste reclamation, and the decision on whether or not to stockpile material can both be made. Also consideration should be given to the mapping and evaluation of all suitable materials surrounding the mine site. They may be potential sources of mine waste cover material. This cover will provide a medium better suited to plant growth and the development of a self-sustaining vegetative community than mine waste materials without such cover.

SUMMARY

At the Second Annual British Columbia Mine Reclamation Symposium held in Vernon in 1978, J.D. MacDonald, the senior reclamation inspector for the B.C. Ministry of Energy, Mines and Petroleum Resources stated: "Reclamation in British Columbia cannot be defined by a set of regula-

Figure 4

SOIL MAP COMPILED FROM AERIAL PHOTOGRAPH IN FIGURE 1

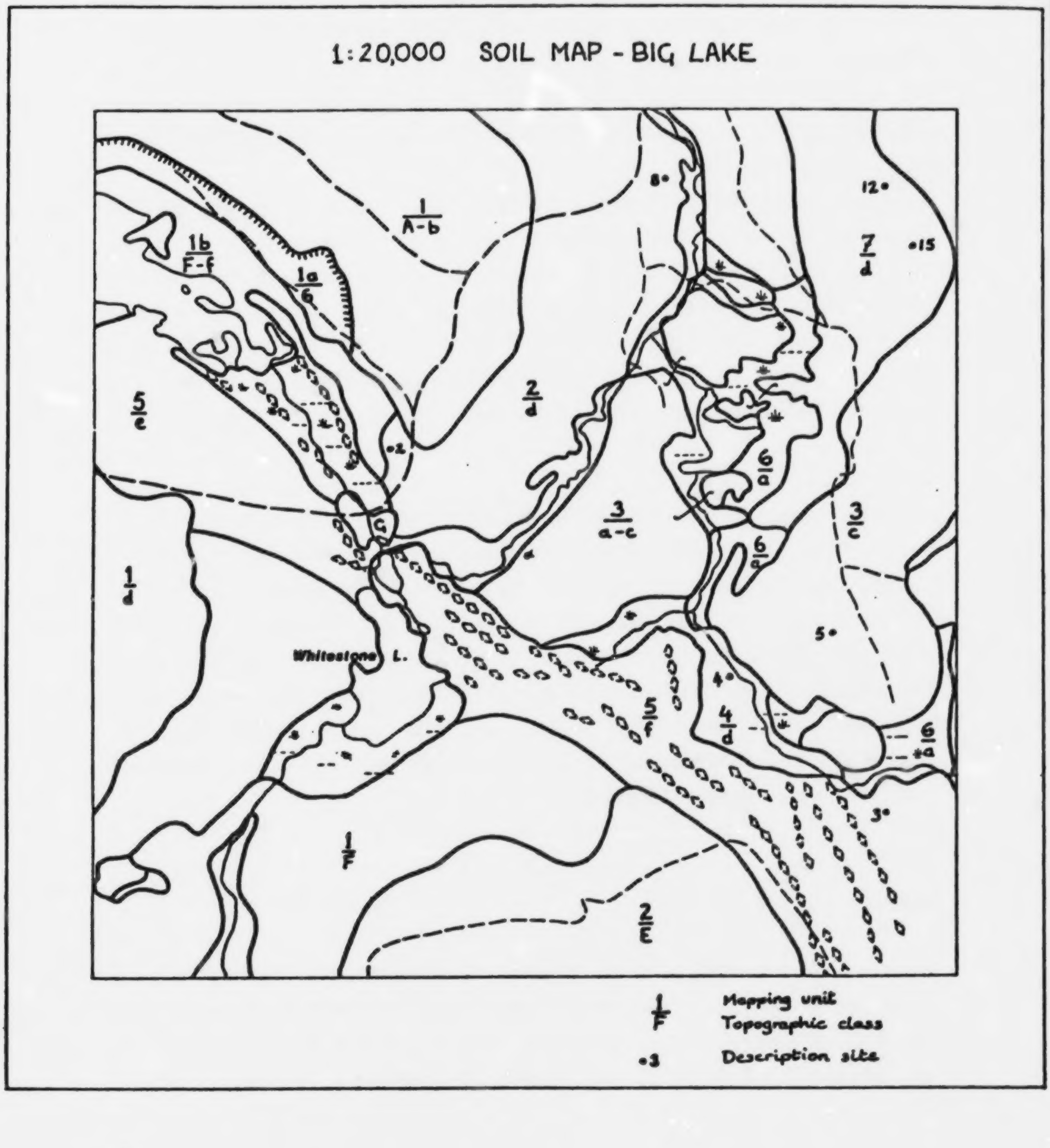


Table 2

SIMPLIFIED LEGEND FOR USE ON SOIL MAPS

MAPPING UNIT	TERRAIN	TEXTURE	SOIL DRAINAGE	SOIL CLASSIFICATION	SIGNIFICANT CHARACTERISTICS	SUITABILITY AS SOURCE OF COVER MATERIAL
1	morainal blanket	$\frac{\text{CL}}{\text{C}}$	MW	BR.GL	highly compacted ground moraine at depths 100 cm	poor
1A	morainal blanket	C	MW	GL	severe erosion, rapid runoff	nil
1B	morainal blanket	C	MW	BR.GL	pitted and hummocky capping of GS veneer	poor
2	morainal blanket	GSL	W	BR.GL	inclusions of coarse textured morainal veneer	fair
3	morainal blanket	SCL	W	BR.GL		good
4	glaciofluvial veneer over morainal blanket	$\frac{\text{VGS}}{\text{SCL}}$	W-R	O.DYB	excessively stony and gravelly	poor
5	glaciofluvial blanket; ridged	GS	R	O.DYB	moderately stony	poor
6	organic	MESIC	VP	TY.M	inclusions of well humified forms and calcareous layers	nil but useful as soil amendment
7	morainal veneer over glaciofluvial blanket	$\frac{\text{GCL}}{\text{GSL}}$	W-R	O.DYB	morainal veneer is discontinuous	fair

tions or legislation because of the extreme variances of physiography, biogeoclimatic zones and elevations. We have mines in the dry belt of the Okanagan, the rainbelt of the coast having 240 inches of rainfall a year, elevations of up to 7,000 feet and in nearly all cases little or no topsoil." I agree with the first part of his statement and, if by the term "topsoil" Mr. MacDonald means deep organic mineral horizons suitable for crop growth, I agree with the whole. However, if he is implying that there is very little if any soil suitable for use in reclamation present within the mine sites of B.C. then I take exception.

I have mapped soils ranging from the Canada/U.S.A. border north to Fort Nelson and from elevations at sea level all the way up to some 3,500 masl, and I think many of us would be surprised if we looked closely at the soil resources available. To support this statement I would like to refer to a soil transect on the Belcourt property of Denison Mines that was mapped by Phil Christie during the soil survey he carried out for Denison this past summer.

The Belcourt property lies in the northeast coal block due south of Dawson Creek and due east of Prince George on the B.C./Alberta border at an elevation of between 900 and 2,000 masl. This potential coal property would be mined by an open pit process which would result in the removal of deep geologic strata as well as any overburden material as extensive pit areas are developed. The transect extended from the crest of a mountain ridge in the subalpine environment down to the upper mountain slopes within a potential mine site. On first appearance the entire ridge appeared to be composed of bedrock at or near the surface with only very shallow soil cover interspersed between bedrock outcrops. On closer inspection as revealed by the soil pit excavation at Site 1, the rocky material at the surface was in the form of stone stripes created by the intense subalpine environment and, in fact, there was a soil present that was deeper than expected. It should be noted that on photo interpretation and in the reconnaissance mapping process this ridge was determined to be predominantly bedrock at the surface. The texture of the soil material ranged from sandy loam near the surface to silty clay over bedrock at a depth between 60-75 cm. This Site 1 pit was located approximately 25 metres downslope from the ridge crest. A soil profile obtained at the Site 2 pit located approximately 25 metres further downslope showed that the soil depth increased to approximately 1 metre. Further soil pit sites along the transect showed a continuing increase of soil depth down the slope up to a depth of 3 metres in the forested area near the timber line. Much of the deposits in which these soils formed would be rated as fair according to Table 2. Within the proposed mine site area many other soil deposits occur which are also potentially suitable for use as cover material and could be considered for stockpiling. This was particularly evident near the mine site. Also an organic soil deposit was mapped in a depressional area in the vicinity of the ridge crest. Much of this organic material, again in the vicinity of the mine site, is potentially suitable for use as a soil amendment.

In my view, to attain a self-supporting vegetative community, the use of existing natural soil materials for covering mine wastes will prove more practical than the expensive, continued support of plant growth using fertilizers and irrigation applied directly to the waste material.

In summation, I believe that by undertaking sufficiently detailed soil surveys and soil sampling programs we will be able to develop reclamation programs for many potential mine site areas throughout the province that will far surpass attempts at reclamation without this knowledge. I recognize that there are many important considerations not considered in this paper. Such topics as materials handling, stability of stockpiles and, maybe most important, the economic feasibility of utilizing soil material as a cover source have not been discussed. These are all matters that will have to be considered in any comprehensive reclamation program.

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DISCUSSION RELATED TO P.A. CHRISTIE'S PAPER

Questioner Unidentified: At what elevation were the soil pits?

Answer: The transect ran from an elevation of 1700 metres at the ridge crest, then down to the timberline to a point 300 metres below it.

Questioner Unidentified: What was the average slope?

Answer: About 15 degrees.

Bill Herman - Pacific Soils Analysis Inc.: Some of the problems associated with vegetation, raised at the 1979 Seminar, resulted from toxicity levels of some of the elements - regardless of whether they were nutrients or not. I'm wondering if anyone has contemplated using organic amendments such as sawdust, as decomposing organic matter has a far greater buffering capacity than mineral soil per se?

Answer: As your Ph.D was in organic soil chemistry, you could probably answer that question better than I. But it does point out why I stress the need for research into the use of organic materials. They are there, and we know that they have these ameliorative capacities. I think they are very important.

R. Hawes - B.C. Research: A major concern is to minimize the areas being disturbed during mining. If you look at the adjacent areas as a source of soils for reclamation, wouldn't you be increasing the area of potential disturbance. In your wetlands example, if you used those soils, would you not also be creating an additional impact on wildlife?

Answer: The wetlands I mentioned were on the mine site and would be lost if the area is mined. I'm not suggesting that we should go out of the mine area and needlessly disturb organic deposits. A gentleman from Cassiar told me that they haul material from up to 20 miles away. Obviously, impacts are associated with the disturbance of natural sites, so it seems to me that if a source of cover material is not available, we're not going to go into the surrounding area to strip topsoil. Such action may well have a horrendous impact. Nevertheless, I have seen many bases where suitably deep unconsolidated surficial deposits do occur which could have been used. You must also consider the Soil Conservation Act and possible difficulties with lands in the Agricultural Land Reserve, but I still think the possibilities are good.

Niel Duncan - Energy Resources Conservation Board, Calgary: Is the compactability of soil material not important? There is a case on the Alberta plains where a lot of money was spent bringing in topsoil. It all washed away in a couple of years, which makes me think that compactability is an important factor.

Answer: That is a significant point. I can only emphasize the need for analysis of these materials. Perhaps mineralogy, excavated fraction analysis, and that sort of thing are also necessary. Other speakers may be stressing this, particularly Susan Ames who will be discussing the soil/spoil interface.

ASSESSMENT OF MINE SPOIL FOR THE ESTABLISHMENT OF VEGETATION

by

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ASSESSMENT OF MINE SPOIL FOR THE ESTABLISHMENT OF VEGETATION

INTRODUCTION

The assessment of mine spoil for the establishment of vegetation requires that information about the chemical and physical characteristics of the spoil be combined with that of the environmental setting of the waste material. In order to completely evaluate a spoil's ability to support plant life, factors of slope, precipitation, temperature and duration of frost-free period must be considered in conjunction with fertility, drainage, texture, available plant moisture, and salinity.

Though some general statements can be made about the qualities of mine spoil, some of the materials exhibit idiosyncracies which challenge reclamationists. The environmental setting is interesting in that much of it is artificial (e.g. topography and slope) and can therefore be manipulated to serve particular purposes.

This paper discusses the inherent variability of physical and chemical criteria in mine spoils and how these variables affect plant establishment and vegetative growth. Sampling strategy is also examined, as are analytical techniques crucial to plant growth appraisal, though the latter are included with a word of caution. As Mr. P. Christie previously covered the management of topsoil and overburden, only waste rock and tailings are considered in this paper.

FACTORS AFFECTING VEGETATION ESTABLISHMENT

The principal factors affecting seedling establishment and plant growth in mine waste rock and tailings materials are spoil stability, moisture retention, drainage, fertility, soil temperature, surface crust formation, heavy metal toxicity, pan formation in materials, salinity and acidity. Individually or in combination, these properties can threaten plant establishment and/or retard vegetative growth. Commencing with spoil stability, each of the properties will be discussed in terms of how it affects the opportunity for successful reclamation.

SPOIL STABILITY

The stability of deposited waste rock and tailings is of major concern to mine operators and reclamationists. For the operator, fitting spoil volumes into available areas to minimize land occupancy and disturbance is an engineering problem; whereas, the reclamationist is primarily concerned with spoil construction as a precursor to successful reclamation.

In general, waste rock and tailings provide a consistent environment for the establishment of seedlings, and a stable surface increases the possibility of vegetative growth. The irregular shape and size of the coarse fragments provide shelter from wind and water erosion for the germinating seedlings. Field observations have indicated that pockets between coarse particles act as microcatchments for moisture, nutrients, and fine particles. Such microhabitats can also protect young plants from the extremes of temperature.

Stability in waste rock piles is dependent upon the slope angle. If deposition results in a slope which is too steep, as may occur where a dump is steep walled to conserve space, a rock slide may occur. Revegetation will be impossible unless slope angles are reduced.

Instability has also been documented in dumps composed largely of sedimentary material. Sedimentary deposits are easily broken down, consequently they slump. Therefore, slope angles of dumps containing sedimentary host rock should be less than those which contain more competent materials.

In order to stabilize tailings materials, they must be supported by reinforcing structures or dams because they are subject to slumping when saturated with water. This tendency to slump is a direct consequence of the particle size distribution of the spoil. Tailings material is finely crushed rock that is deposited in the form of a slurry. This spoil is less than 2 mm in diameter and tends to be sand size. The stabilizing effect of coarse fragments combined with fines is absent in tailings. Recycling of excess water drained from the ponds helps to alleviate the slumping problem.

Instability also occurs on the spoil surface. Tailings are susceptible to extreme water erosion, and heavy rainfall rapidly scours the surface of the ponds, carrying away fines as a slurry. Immature plants are often buried or removed in the rivulets. Water erosion of tailings is under the scrutiny of government agencies. Environmental impact studies have included incidences where fines have been discharged into streams. The deleterious accumulation of fines in spawning grounds may smother fish eggs and bottom vegetation. The cardinal approach in preventing water erosion of spoil surfaces is to establish a vigorous and uniform vegetative cover.

Wind erosion is a common problem on dry tailings spoil devoid of vegetation. The level topography of impoundment areas offers no protection from air currents. Airborne particles have the effect of sand blasting plants seeded on the spoil. The rapid establishment of a vegetative cover will help to prevent particle transport. In some circumstances mulching, or the application of manures, soil and overburden have discouraged wind erosion.

MOISTURE RETENTION

The low moisture holding capacity of waste rock and tailings has caused some major problems in establishing self-sustaining plant communities on spoils in dry climates. Water retention is determined by particle size distribution and organic matter content. The water holding capability of organic matter is attributable to its high percentage of small pores, and the surface charges which hold onto water molecules. Organic matter can also increase the volume of small pores by binding together coarse particles such as sand. This favourable material is negligible or absent in both waste rock and tailings; therefore, the moisture retention characteristics of such spoil become a function of particle size distribution and coarse fragment content.

The moisture holding capacity of waste rock is substantially lower than that of tailings, because for equal volumes of both materials, waste rock has a lesser proportion of fines. Waste rock contains a fine fraction that is about 1.6 mm in size. Abrasion between coarse fragments during truck handling produces some of these fines. However, most fines are sand size, thus particle spacing is large enough to let water drain easily from the pores, leaving little available water for plants.

Fines are not evenly distributed in waste rock. They are generally more concentrated near the top of the rock pile, since gravity draws the heavy coarse fragments towards the toe of the dump.

The volume of fines in waste rock spoil may be substantially increased when coarse fragments are broken down into fine particles. As noted previously, sedimentary spoil weathers fairly rapidly, whereas igneous and metamorphic rocks exposed to atmospheric conditions for long periods may become "rotten", crumbling under the slightest pressure.

Low water retention in waste rock results in droughtiness. The different sized coarse fragments create large voids in the rock dump which allows precipitation to leach through the pile, thus moisture is unavailable for surface vegetation. Drought resistant species or irrigation programs may be used to offset the effects of water deficiencies. An irrigation program will stimulate initial vegetation establishment, but may encourage moisture-loving plants that exclude drought resistant species. When the water supply is terminated, moisture-loving plants become water stressed. The addition of fines (<2 mm) to waste rock would serve to alleviate these water retention problems, provided that over-irrigation or heavy rain does not wash out the fines from the voids. Alternatively, mulches which tend to mat and/or bind may be added to waste spoil because they reduce evaporation and retain water.

Desiccation in vegetation due to low moisture retention, particularly in sand-size tailings, is common in dry climates. In such cases, the use of drought resistant plants or irrigation is required. As with rock spoil, any moisture-loving plants cannot survive without supplemental water. Surface ridging to provide microcatchment depressions in tailings impoundments may help to retain available moisture, or alternatively, mulches, soil and overburden laid on the surface or mixed into the tailings material have been known to improve moisture retention in dry climates.

Green manures may also improve the water-holding capacity of tailings. Some companies in recognizing the pitfalls of irrigation in dry climates, prefer to irrigate solely to establish an initial ground cover; then, in the following season(s), the vegetation is plowed-in. However, the use of green manures is not always successful, because some reclamationists have observed moisture capacity improvements that were less than predicted. This occurred because the decomposition of the plowed-in plant residues was slower than that of the neighbouring undisturbed soils. Reduction in the rate of breakdown has been attributed to the absence of microbial decomposition.

Water retention problems may be less severe in tailings that contain a higher proportion of silt and clay sized particles, and consequently a more evenly distributed particle size. However, water retention is often not uniform over the pond surface, an unevenness which results from the segregation of similar sized particles into horizontal layers. During the deposition of the spoil, coarse particles settle near the inflow while the finer sizes are carried farther into the depressed areas of the pond. Planning of irrigation systems and species selection may be chaotic due to variability in the impoundment area. Deep cultivation of the surface (20-50 cm) may be required to establish homogeneity and thus make reclamation prescriptions simpler.

DRAINAGE

Desiccation of vegetation in tailings spoil can be made worse by the drainage characteristics of the impoundment area, based on the fact that tailings are usually well drained. Rainfall and irrigation water are rapidly removed from the surface as a result of the tailings' generally coarse texture and geographical setting in the design of the disposal area. Tailings ponds are often located in low areas and are gradually built and dammed at their open ends. Impoundment structures 20 metres high are not uncommon. The effect of a deep permeable material and the absence of a hydrologic barrier such as bedrock produces low water tables in the pond. The combination of a permeable material, the elevated position of the tailings surface and the low water table causes rapid drainage in tailings spoil.

FERTILITY

Waste rock and tailings are generally considered to have a low native fertility, because the basic nutrients required by plants are either negligible or absent. The deficiency of these important elements is attributable to the absence of organic matter, which plays a key role in the recycling of nutrients. The needed elements can be released into the rooting zone in a form available to plants only during the accumulation and decomposition of organic residues.

Development of a fertile system in mine wastes is retarded by the inability of the material to retain nutrients. The matrix of spoil generally lacks the clay size particles and organic substances, which provide charged surfaces that attract and bond nutrients. Fertilizers and/or the use of nitrogen fixing plants and green manures are commonly employed to alleviate low fertility in waste rock.

Research has been conducted on the use of native species to increase fertility. Ziemkiewicz (1979) studied the recycling of nutrients on coal wastes and found that native species possess a root-based cycle that returns a high proportion of the nutrients to the system below ground. Agronomic species on the coal wastes recycled 50 percent of their nutrients through their roots and 50 percent through detritus on the surface. The detritus system is less efficient and therefore retards fertility development.

SOIL TEMPERATURE

In some circumstances surface temperatures of spoil discourage seedling establishment. Unprotected seedlings are often scorched by excessive temperatures, a phenomenon common on black spoil such as coal wastes where the dark colours absorb heat. Temperatures as high as 70°C have been recorded at the air-spoil interface of coal wastes (Harrison, 1974). Surface configurations of rock waste influence soil temperatures. An uneven surface provides protection for plants during extreme heat and cold, including frost; for the level surfaces of tailings, mulching or ridging the upper 5 to 10 cm may partially control temperature and provide a favourable microenvironment for young plants.

SURFACE CRUST FORMATION

This phenomenon is specific to tailings ponds. Cracking and crusting are considered to be the result of wetting and drying cycles and the extremes of temperature. Such crusts may prevent the emergence and growth of seedlings and interfere with water movement down to the rooting zone. Cultivation can solve the crusting problem.

HEAVY METAL TOXICITY

A major pollution concern with mine spoil is the presence of heavy metals in toxic concentrations. Heavy metals can leach into the groundwater, thereby contaminating aquatic ecosystems and the drinking water supplies downstream.

Terrestrial wildlife habitats may also be polluted by toxic metals in spoil or in soils adjacent to mine sites. Vegetation growing on the materials can become contaminated through assimulation, converting them to damaging or lethal food for browsing animals.

Heavy metals can interfere with healthy maturity and growth of plants. Research by Berg and Vogel (1968), using greenhouse legumes, investigated heavy metal toxicities in acid mine spoil. While attempting to set up a visual index of metal toxicities, they found that excess soluble manganese and aluminum retarded normal plant development. Studies on the toxic effects of particular metals are complicated by the many chemical interactions which can occur. Results are dependent on the proportions of interacting heavy metals and the various plant species.

Metals frequently encountered in mine waste include zinc, copper, iron, lead, nickel, and molybdenum (Lavkulich et al., 1975-1977; Como, 1978; CANMET Pit Slope Manual, 1977). Incidences of more exotic elements such as arsenic, cobalt and mercury are also mentioned periodically in the literature (McIlveen, 1978).

Gaseous toxins have also been documented. Sulphur dioxide and fluorides are hazardous to perimeter vegetation and soils; and trees, shrubs, grasses, etc. are singed by sulphur dioxide burns.

Management of toxic metal concentrations in mine spoil often includes liming. Liming renders most metals insoluble by raising their pH. Mulches have also been observed to raise the pH of a spoil sample and thus reduce its metal toxicity (Berg and Vogel, 1973). Organic matter is important because it can tie up metals and reduce metal concentration in spoil. The inclusion of metal tolerant plants in the reclamation program offers a feasible solution to these kinds of problems. Also, burial of contaminated spoil has been tried in an attempt to isolate toxic elements from the ecosystem.

PAN FORMATION IN MATERIALS

Tailings high in iron sulphides (pyrite and/or pyrrohotite) are associated with the formation of irreversible hard pans caused by the oxidation of iron sulphides. The resulting iron oxides complex tightly and solidly.

Growth of the pans occurs at the surface and at irregular intervals of depth, spacing and thickness where crevices expose underlying reduced sulphides to oxygen. In the consolidated state, bulk densities of the pans are high resulting in insufficient pore volume for the gaseous exchanges required by plants, and for root and water penetration.

Hydrology of the pond is also disrupted by the indurated horizons as evidenced by impediments to water vertical and lateral movement which results in broken and irregular flow patterns. Pan destruction by standard cultivation equipment has proven to be futile. One possible solution may be to cover them with soil or overburden.

SALINITY

Many mining companies have to take steps to overcome salt accumulations in fine textured tailings spoil, particularly in dry climates. Water movement is too slow to carry salts deep enough into the spoil before evaporation raises and concentrates them near the surface. The problem can be reduced by controlled sprinkler irrigation. If water is applied at a rate equal to the hydraulic conductivity of the material to be leached, salts can be moved deep into the profile beyond the range of high evaporation rates.

Salt tolerant species such as Bermuda grass and Western wheat grass may also be a practical means of vegetating saline spoil (U.S. Salinity Laboratory Staff, 1954). Extreme leaching or recourse to salt tolerant species may not be feasible in all cases, however. The formation of impermeable crusts on iron sulphide tailings spoil may nullify the application of these ameliorative techniques. The ferrugenous crusts prevent root penetration and vertical movement of water, and the salt concentration is extreme - Gardiner (1975) noticed that salt crystals extensively coat the surface of the spoil pond. Burying the spoil may once again be the best solution in this situation.

ACIDITY

Acid generating spoils have created difficult reclamation problems, particularly those related to plant establishment and the overcoming of heavy metal toxicities. Documented research has been undertaken mainly using acid coal wastes. The coal deposits in Kentucky, Pennsylvania, and Montana are high in sulphides. Pyrite is the dominant acid producer because the sulphur in pyrite is oxidized to sulphuric acid. Extreme acid production is also common in iron sulphide tailings. Some research studies have attempted to deter the oxidation of acid spoil to prevent the initial production of acid. Techniques such as flooding acid spoil and sealing it off with clay have been considered (Craze, 1977). Experiments have also been conducted to monitor factors which affect oxygen movement in spoil (Pionke and Rogowski, 1979). Kuja and Hutchinson (1979) approached the acid problem by examining unusual species of plants flourishing in low pH environments in the Smoking Hills of Cape Bathurst, N.W.T. They are hoping that these acid-resistant species can be used in reclamation programs on acid wastes.

Liming has been the conventional treatment for acidic spoil. However, liming is impractical on spoils which continually produce acids (Duncan and Walden, 1975).

Spoil is often buried in order to isolate the material from the environment. Some states in the U.S. exercise strict regulations to control the placement of acid producing wastes; for example, acid spoil must be buried under at least one metre of soil or overburden. However, covering a high acid-generating potential spoil with soil or overburden may result in contamination of the covering medium as acids migrate upward. A barrier of plastic or gravel could be used to separate acidic tailings spoil from the soil or overburden. Rock dump material from the mine site has been found to be a successful gravel barrier (Ames, 1980).

Table 1 summarizes the physical and chemical characteristics of waste rock and tailings deposited at mine sites. They are factors detrimental to successful vegetative reclamation and they must be considered in reclamation planning.

SAMPLING

This section outlines some strategies used in inspecting and sampling a site. They are not meant to be hard and fast rules, but they will serve as guidelines. Since mine waste areas vary in size, construction, configuration, and material, the reclamationist should make an on-site inspection. The spoil site should be traversed while looking for variations in material texture, colour, bearing strength differences and other factors that are important to plant growth. One common practice is to draw a small map of the disposal area indicating slopes, aspect and streams.

The heterogeneity of the tailings and spoil should be taken into account when sampling. Depressed areas of tailings ponds should be

Table 1

FACTORS AFFECTING VEGETATION ESTABLISHMENT IN MINE SPOILS

Waste Rock	Tailings
- 80% coarse fragments (gravels, cobbles, boulders)	- generally sandy texture (100% ~ 2 m)
- sandy texture (~ 2 mm)	- well drained
- rapidly drained	- unstable (to wind and water erosion)
- stable (to winds and water erosion)	- crust formation and cracking
- low organic matter	- hardpan formation
- low nutrient holding capacity	- differential layering
- low water holding capacity	- low organic matter
- low native fertility	- low nutrient holding capacity - low water holding capacity - low native fertility - heavy metal toxicites - acidity - salinity - toxic gases

sampled as well as the perimeter of the impoundment area. As noted previously, fines generally settle in low sections while coarser particles collect near the inflow of the tailings slurry. Ten sampling sites per hectare is recommended for spoil that is homogeneous (CANMET Pit Slope Manual, 1975). A standard grid pattern for site location can be used on uniform waste materials.

Once the sampling sites have been located, pits at least one metre deep should be dug. The depth requirement is based on the rooting depth of many plants, and is important in assessing potential water retention and drainage capabilities. It should be remembered that with cereals such as oats and wheat, root systems may penetrate to a depth of 1.5 to 2 metres; while alfalfa and other drought resistant plants, may sink their roots up to 5 metres.

Where vertical differences occur in the pit being sampled, the samples obtained for analysis should weigh 200 to 300 grams each (CANMET Pit Slope Manual, 1975). Field notes should include the locations of hard pans and impermeable layers, and describe variations of particle sizes and colours. The latter are significant because they indicate mineralogical and/or chemical changes in the spoil material.

ANALYSIS

The collected field samples should be analyzed to assess the potential of mine spoil for plant establishment. A list of tests as guides for the appraisal of spoils is given, and supplementary information is added where it is felt to be necessary. See also cautionary statement in the "Use of Standard Analysis on Mine Spoil" - the next chapter. Reference should be made to the CANMET Pit Slope Manual (1975) in order to compare results with the case histories of other mine waste analyses.

PHYSICAL ANALYSIS

Particle Size

By this method the fraction smaller than 2 mm is separated into the sand, silt and clay portions by weight. The analysis will provide data related to the stability and water retention properties of the spoil.

Water Retention

Water retention curves should be drawn. Points on the curve indicate the water storage capacity of the spoil, thus giving an estimate of the material's ability to store water to meet plant needs. Figure 1 presents the water retention measurements for three different horizons in the Endako (Central British Columbia) tailings. The water retention curve for an average loam soil has been included for comparison. The 96-100 cm layer of the Endako spoil has a higher water content than the average loam soil. The 96-100 cm horizon is dominantly silt and clay sized particles; whereas, the particle content of a loam is roughly 17% clay, 38% silt, and 45% sand. Because of the greater proportion of fine particles, in the Endako horizon, it has a greater moisture retention.

The Endako curves at 0-4 cm and 25.5-59 cm indicate the sandy nature of these horizons. The abrupt decline in the moisture contents at less than 1 bar is due to the rapid drainage caused by the high percentage of large pores. The low moisture content in the 3 to 15 bar range, represents the range at which water is available to plants.

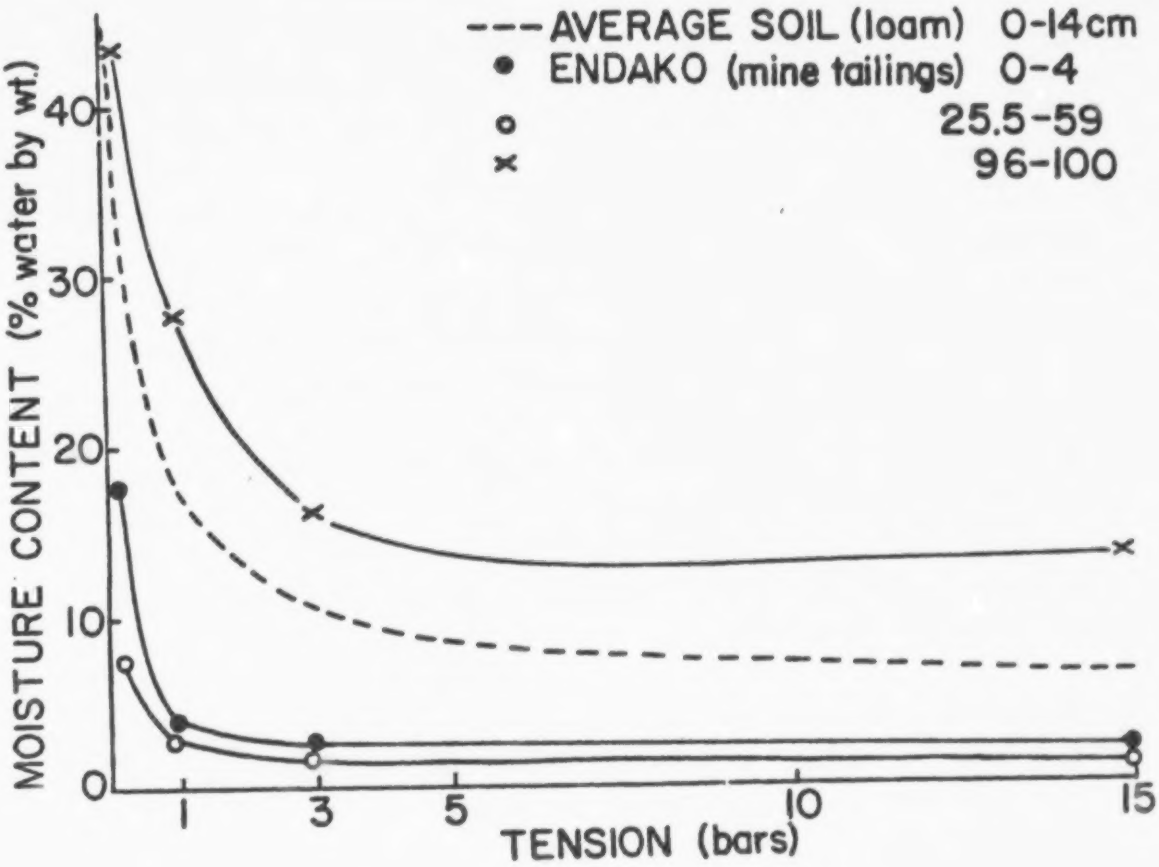
It is interesting to note that the Endako tailings material was not uniform throughout the sample pit, as evident in the three different curves used to represent three horizons. If the spoil had been uniform, all three curves would be superimposed.

Particle Density

The value of the particle density of the less than 2 mm size fraction

FIGURE 1

WATER RETENTION CURVES[c]



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[c] From: Tailings Research, Selected Mines, British Columbia 1976-1977. (Lavkulich *et al.*, 1977).

is important during particle size analysis because it enables calculation of the spoil porosity.

Bulk Density

The particle density included in the porosity evaluation, when combined with the bulk density, can be used to determine the degree of compaction or cementation in the spoil (i.e. porosity).

Bulk density measurements correlated with particle size analysis indicates the proportion of coarse fragments in the volume of rock dump spoil. This test can be performed on-site.

CHEMICAL ANALYSIS

Available Nitrogen, Phosphorus and Potassium - These primary nutrients should be determined by chemical analysis to assess fertility.

Soil Reaction - pH - This can be done in the field. Most plants prefer a range from about 5 to 7.

Salinity - Electrical conductivity values greater than 4 mmhos/cm are deleterious to most plants.

Extractable or Available Metals - The elements include iron, nickel, lead, cobalt, arsenic, cadmium and molybdenum. Excessive amounts of these metals may be toxic to plants and animals.

Cation Exchange Capacity - The test for cation exchange capacity is used to estimate a material's nutrient holding capacity.

Exchangeable Cations - The distribution of calcium, magnesium and potassium (nutrients necessary for plants) is ascertained in this analysis. These elements may interfere with one another or with other nutrients in plant uptake if they are present at certain proportions.

Soluble Salts - Data on the species and amounts of soluble salts present in a soil or spoil material are useful in predicting their effects on plant health and growth.

Sulphur - The sulphur test is important in predicting the acid producing potential of spoil. This test requires separation of the sulphide from the sulphate form of sulphur.

USE OF STANDARD ANALYSIS ON MINE SPOIL

The previously outlined standard tests were developed for the analysis of soil material (Black *et al.*, 1965). Caution should be used when adopting these techniques to mine spoil. Improper use or failure to make some necessary adjustments during the tests, will lead to erroneous results and, thus, perhaps invalidate any predictions. A few examples follow.

PARTICLE SIZE ANALYSIS OF MINE SPOIL

Particle size analysis illustrates the need to make adjustments in analytical techniques.

Particle size analysis is based on Stokes Law:

$$v = \frac{d^2 g(\rho_p - \rho_1)}{18\,\eta}$$

where v = velocity
d = diameter of particle
g = gravity
ρ_p = particle density
ρ_1 = density of liquid
η = viscosity of liquid

The proportion by weight of sand, silt and clay can be determined for a sample. The formula is based on the rate of descent of a particle of average particle density through a solution (water) of particular viscosity. This analysis must be modified when estimating the particle sizes of mine spoil, in order to compensate for the differences in particle density of certain mine wastes. For example, the iron tailings (Sullivan Mine, Kimberley, B.C.) have a particle density of 3.9 compared to the average soil particle density taken as 2.65. Failure to modify the standard method of this test, may result in a particle size analysis which gives a too high sand, and perhaps silt size fraction. The reason for the discrepancy is that the heavier but smaller particles will fall as rapidly as a sand size particle of average soil particle density.

In the case of coal spoil, fine particles float on water, consequently, new methods of particle size distribution need to be developed. One approach could involve the use of a less viscous solution so that the coal particles will sink. Kerosene has been suggested; however, if this or any other solution is used, the viscosity of the new medium will have to be incorporated into the Stokes Law formula.

ORGANIC MATTER IN COAL

The carbon content method of estimating the organic material in coal needs to be adjusted. The Leco method burns off all the carbon and ultimately yields a measure of "total carbon". The Walkley Black method is based on measurements of active or fresh organic matter as opposed to charcoal. However, this latter method has not been researched, and it is not known if the acids in the Walkley Black method break down the edges of the coal grains. Perhaps a combination of the two carbon methods may improve the technique of estimating organic matter in coal.

FERTILIZATION REQUIREMENTS

The relationship between crop production and fertilization has been correlated in agricultural soils. Similar trials are needed for mine spoil. Plant growth response to fertilization in agricultural soils is determined by phosphorus and potassium fixation as well as many other factors. Methods of testing phosphorus and potassium fixation in mine wastes should be established, supplemented by field trials and greenhouse experiments to measure crop response. Some related work has been undertaken (Como et al., 1978; Gardiner, 1978).

REPRESENTATIVE BRITISH COLUMBIA MINE SPOILS

Tables 2 and 3 identify some of the physical and chemical characteristics of mine spoil from four British Columbia mines. Data for an average soil (loam) is included for comparison.

The Kaiser (Sparwood, B.C.) mine provides an example of coal spoil. The Sullivan (Kimberley, B.C.) siliceous-iron tailings contains iron sulphides, and is therefore an example possessing a high particle density, high salt content and a potential for acid production. Lornex (Highland Valley, B.C.) and Similkameen (Princeton, B.C.) are examples of "average" mine wastes.

PHYSICAL CHARACTERISTICS (TABLE 2)

Particle size analysis for the Kaiser (Sparwood) mine tailings is incomplete, due to the lack of information on silt and clay size fractions. Perhaps this is indicative of the difficulty in particle sizing coal spoil.

Variation in particle density due to differences in mineralogy of the four spoils is evident.

Table 2

PHYSICAL CHARACTERISTICS OF REPRESENTATIVE B.C. MINE WASTE MATERIALS*

Sample	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture	Fine < 2 mm (%)	Coarse Fragment > 2 mm (%)	Particle Density (gm/cm^3)	Bulk Density (gm/cm^3)	Total Porosity (%)	Field Capacity Water Content (cm/cm)	E.C. (mmhos /cm)
Average Soil (loam)	0-14	17	38	45	loam	90	10	2.65	1.33	46	.33	
Kaiser Tailings	0-26	—— 47 ——		53	-	100	-	1.37	-	-	-	.81
Sullivan Si-Fe Tailings	70+	2	31	67	sandy loam	100	-	3.34	1.86	44	.19	19.2
Lornex Tailings	78-98.5	8	44	48	loam	100	-	2.57	1.12	56	.37	2.0
Similkameen Waste Rock Dump		13	24	63	sandy loam	21	79	2.77	1.58	36	.11	

*Mine waste data from Lavkulich _et al_., 1977 and Lavkulich _et al_., 1975. Soil data from Brady, 1974.

Table 3

CHEMICAL CHARACTERISTICS OF REPRESENTATIVE B.C. MINE WASTE MATERIALS*

Sample	Depth (cm)	pH (.01 M $CaCl_2$)	N (%)	Available P (ppm)	% OM (LECO)	C.E.C. (me/100g)	— Exchangeable Cations — Ca^{++}	(me/100g) Mg^{+}	K^{+}	% S
Average Soil (loam)	0-14	6.5	.25		4	14	17.6	8.0	17.4	.10
Kaiser Tailings	2-26	5.7	.35	7.0	100	2.8	5.5	.15	.13	.16
Sullivan Si-Fe Tailings	70+	4.0	.006	1.2	11.2	2.8	18.2	2.0	.14	7.39
Lornex Tailings	78-98.5	8.3	.006	1.1	.46	4.3	17.5	.35	.19	.02
Similkameen Waste Rock Dump		7.3	.008		.61	18.3	26.2	5.2	.33	-

*Mine waste data from Lavkulich _et al_., 1977 and Lavkulich _et al_., 1975. Soil data from Brady, 1974.

Under the table column heading, "coarse fragment", it should be noted that 79% of the Similkameen waste rock spoil comprises cobbles and gravels.

Salt production through iron sulphide oxidation in the Sullivan siliceous-iron tailings is extreme (E.C. = 19.2 mmhos/cm), compared to an average soil (loam) and the other listed spoil materials.

CHEMICAL CHARACTERISTICS (TABLE 3)

The organic matter content of 100% for the Kaiser wastes material emphasizes the need to develop new techniques for measuring organic matter in coal spoil.

All the examples in this table, except the Kaiser coal spoil, have insufficient concentrations of phosphorus and nitrogen compared to an average soil (loam). In addition, cation exchange capacities are below average for these types of spoils.

CONCLUSION

The characteristics of mine spoil materials are variable and site specific. Assessment of the wastes prior to the establishment of vegetation necessitates combining information about the environmental setting of the disposal site and the physical and chemical properties of the spoil. Most mine waste materials are infertile, lack organic matter, and have poor water retention and nutrient holding capacities.

Complete assessments of collected samples must include thorough sampling programs followed by appropriate chemical and physical analysis. It is evident that further research into the development of new analytical techniques as "tools" for assessing mine wastes is required.

Finally, the reclamationist must recognize that some spoils exhibit unusual characteristics and, therefore, must be aware of the potential problems and how to overcome them.

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DISCUSSION RELATED TO S.E. AMES' PAPER

Si Brown - Acres Consulting Services Ltd.: You mentioned that most of the tailings have a high clay fraction.

Answer: No. A low clay fraction.

Si Brown: (Distorted recording. The question related to the existence of relatively high clay fractions in tailings.)

Answer: The clays are very important in soils. Clay particles are very small and their surfaces are reactive. They have charges that help to retain cations because the general surface charge of clays is negative. Because clay particles are small, the spoil has smaller pores, and the particles hold the nutrients and water more effectively. Sandy material is very coarse, so the nutrients generally don't adhere to the sand surfaces.

Questioner Unidentified: (Distorted recording. The question related to soil aeration as it pertains to the generally sandy structure of tailings.)

Answer: Tailings are generally on the sandy side, so one of the main problems with tailings is that they don't have very much structure. They don't have a buildup of organic matter, and the sandy grains haven't been weathered, consequently, the minerals important to plants aren't weathered out. As a result, although the particle size might not be too much of a disadvantage, the tailings are usually lacking in nutrients.

Niel Duncan - Energy Resource Conservation Board, Alberta: One of the problems with tailings is that perhaps only twenty percent is coal, and most of it is clay. Flocculant is added to try to settle the clay and some coal particles. Does this flocculant cause any problems with reclamation? Is there a flocculant which would respond better to reclamation than others?

Answer: I don't know much about the use of flocculants in coal. I think they might be a positive help because flocculants would promote structure and stability. If you flocculated tailings, they would have a greater potential structure. It depends, too, upon the chemical nature of the flocculant. If the flocculant is chemically adverse, then it wouldn't be advisable to use it. Adding organic matter would be a better approach. Although not usually available at a mine site, organic material could improve structure, help to retain nutrients, and enhance moisture holding capacity. Flocculants might help if the flocculating agent is used to flocculate the coal particles in coal tailings.

Niel Duncan: They try to coagulate the clay in larger sinks so that you have flocculant in the decant.

Answer: I understand.

Niel Duncan: I'm wondering if the utlimate ability to reclaim is a consideration in the choice of a flocculant?

Answer: It should be. But again, you should look at the chemical nature of the flocculant.

Jim Robertson - Acres Consulting Services: A number of chemical flocculants do in fact act by tying up cation exchange sites, resulting in a loss of complimentation.

Answer: That's correct.

Jim Meir - Byron Creek Collieries, Alberta: The basic consideration with waste dumps is the particle size. Have any studies been done on the breakdown time or the weathering time of the rock?

Answer: Dr. Lavkulich has a very good slide of interest to you. It shows a person holding a piece of rock and crushing it in his fingers. If you have a very rotten rock, it will break down even faster. Sandstones tend to break down more slowly than fine textured sedimentary rock. I don't know if much research has been done on the breakdown of rock. If the rock breaks down easily, you get more fines, and it is easier to reclaim because the fines are there. The fines help to hold the moisture and act partially as a seed bed for the seedlings.

Ernest Portfors - Klohn Leonoff Consultants: The slides you had of tailings, generally showed very dry sites. Have you ever considered a situation where whole tailings are recycled, sand fractions taken out for dam construction, and the storage of slimes? The slimes probably have a high water content.

Answer: These kinds of situations can occur. When iron sulphide tailings are deposited in the pond, they are wet, and become reduced. Their surface oxidizes and seals off the exterior, so the moisture remains below the surface. These slags are unstable if they have this high moisture load capacity. Are you thinking of a wetter climate?

Ernest Portfors: No.

Answer: If you are handling that kind of material, it is different than a lot of tailings. Particle size analysis, moisture, and probably some engineering properties should be done because the material doesn't appear to be very stable.

Questioner Unidentified: In your slides you showed tailings. You then proposed to mix them to get a homogenous horizon. You also showed a slide of a gravel bank. Then you proposed to add the gravel. Are you suggesting that all of those activities can be performed by any specific piece of land?

Answer: No. You have to chose your method according to your problem. The reason I put the gravel on was that the tailings were high in acids and some metals, and if you put overburden directly on top of them, the overburden might have become contaminated. Five centimeters of gravel is a very shallow layer, and I think most heavy equipment can't handle less than a foot. A gravel layer acts as a boundary between the tailings, which are contaminants, and the overburden. But I don't think you need gravel in a rock dump.

Peter Bradley: Do you require less topsoil if you place a gravel bed down?

Answer: In the long run you would because if you added a hundred feet of topsoil directly on to those kinds of tailings, you would probably pass away before the topsoil ever became contaminated. I'm not being facetious, but the moral support of the gravel is that it prevents contamination. The depth of overburden on top of a gravel layer should be determined according to the climatic conditions of the area. The gravel below an overburden layer could change the water movement and, if it were too shallow, it could produce a very dry soil. The use of gravel between overburden and tailings may be a problem in areas such as the west coast of Vancouver Island where it is very wet. Heavy precipitation would result in a water table forming on top of the tailings, which would seep into the gravel, and eventually into the overburden. So, the depths of gravel and overburden are dependant upon the climate and chemical and physical properties of the overburden. The reason for the gravel is to create a barrier rather than to lessen the depth of overburden; however, I think it would help to decrease the overburden depth, though. It's difficult to predict how far the contamination would seep upward into the overburden, if it was placed directly on top of the tailings.

Bill Herman - Pacific Soils Analysis Inc.: Does the vegetation grow into the barrier and then into the material below it?

Answer: I don't think the study has been going on long enough to determine that. Bob Gardner would be able to give you more information on that, I think.

Bob Gardner - Cominco Ltd.: The study was initiated in October of 1978, so there has been only one growing season. There has been some indication of contamination moving up into soil without the barrier. The barrier consists of one foot of coarse rock, which is a rock about two inches in size. There is no indication of any contamination moving through the barrier, to this point in time. Vegetation has established itself satisfactorily on the overburden that was placed over the top of the barrier. Those are the results to date.

Bill Herman: Have there been any pits dug to see how deep the roots go? It's great that the barrier is serving to keep the material from moving up, but is it going to keep the roots from going down?

Bob Gardner: The entire soil volume above the barrier should be available for root development, but I doubt very much that the roots will go into the very coarse material of the barrier.

Bill Herman: Do you think it is reasonable to put a vinyl layer below the barrier, keeping in mind that vinyl is not biodegradable?

Bob Gardner: Yes, this is probably another alternative which could be considered.

Ernest Portfors (to S.E. Ames): In your suggested chemical analysis I noticed you didn't include uranium as a trace element.

Answer: Perhaps you are thinking of the Okanagan. Uranium would be something to look for, and you can add it to the bottom of your list. The particular elements I chose were only examples. For instance, arsenic and mercury could be a big problem in Ontario. In a lot of mines they don't have such problems, but if you suspect that your mine materials might contain a certain element, they can be checked. You have to make sure that vegetation and animals that eat the vegetation don't take it up.

C. Guarnachelli - Hardy Associates Ltd.: You were showing slides of a sort of mine, and indicated that the top surface displayed massive leaching while the tailings in the lower part were less acidic. Is that correct?

Answer: If you get an oxidized iron pad forming on the surface that closes off the material from the air, the underneath material will still be reduced. These pads can be quite strong and uniform, since they're not broken. Below a certain depth - I think less than a metre - you can still find reduced tailings, even though the top metre is oxidized.

Questioner Unidentified: I think you indicated that acidity increased as you went down below?

Answer: No, not in the Sullivan mine tailings.

FERTILIZERS AND SOIL AMENDMENTS
IN
MINE RECLAMATION

by

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FERTILIZERS AND SOIL AMENDMENTS

INTRODUCTION

The use of fertilizers and soil amendments for reclamation purposes is, in many ways, similar to their use in agricultural systems. In both situations the main objective is either to totally remove or to ameliorate a limiting plant growth factor(s). In both cases it is desirable to select the appropriate material at the least cost. On the other hand, the reclamationist is often not dealing with natural soils nor is he necessarily striving for maximum biomass production. Understanding unique and, in some cases, unstable growth media and managing for long-term stability of the plant community, assume greater importance in reclamation than dry matter accumulation.

In both agriculture and reclamation work a basic understanding of the fertility level of the growth media and a knowledge of the basic materials available for modifying soil fertility are prerequisites to establishing successful plant growth. In this presentation I have attempted to provide an overview of these topics.

SOIL FERTILITY ASSESSMENT

An evaluation of soil fertility is similar to a doctor diagnosing the health of a patient. The medical doctor observes the patient, obtains all the information possible with his questions, and then makes the appropriate tests. Similarly in plant diagnostic work, we observe the plants, find out as much as possible about the origin, characteristics and past management of the material to be vegetated, and then make tests on the plant or the growth media.

Deficiency of an element may not directly produce visible symptoms. However, it will throw the plant's biochemical processes out of balance leading to a shortage of some organic compounds and an accumulation of others. While each symptom is related to some function of the element in the plant, a given element may have several functions, making it difficult to explain the physiological reason for a particular deficiency symptom. In other cases, the connection between the symptom and the element's function is clear. For example, the chlorotic plant tissue resulting from deficiencies of N or Mg can be directly related to their role as constituents of the chlorophyll molecule. Other elements such as Fe and Mn are involved in the formation of chlorophyll, and their deficiencies also appear in the form of chlorotic tissue.

Another important factor in determining the deficiency symptoms of the various elements is their mobility within the plant. Magnesium, for example, is mobile in plants and the typical interveinal chlorosis resulting from Mg deficiency would appear on the older leaves. Iron and Mn, on the other hand, are immobile in the plant and their deficiency symptoms would appear on the new growth.

Some deficiency symptoms associated with the essential plant nutrients are listed in Table 1. For a more complete discussion refer to Chapman (1966) or Sprague (1964). While the proper interpretation of deficiency symptoms can be a valuable tool, it is always better to practice preventive medicine, i.e. to predict deficiencies before they become serious enough to limit plant growth. Also, one may be faced with a situation in which two or more elements may be simultaneously deficient resulting in confusing visual symptoms. Where possible it is desirable to be able to predict nutrient deficiencies before they occur. One tool which can be useful in this regard is soil testing.

SOIL TESTING

Soil testing attempts to simulate the ability of the plant root system to acquire nutrients over the duration of the growing season. Currently, this involves the use of a chemical extractant which, hopefully, will extract from the soil a portion of the element in question which will correlate positively with plant uptake of that element and hence, growth. It must be stressed that the number derived in the laboratory analysis following extraction of the soil sample is virtually meaningless without same backup research both in a controlled environment and in field plot studies. It is dangerous to extrapolate from one agricultural soil to another, much less from agricultural soils to mine wastes.

With this precaution in mind, there are a number of soil test extractants available for most plant nutrients, under a variety of soil conditions (Table 2). Instrumentation for determining the various nutrients in the extracting solutions is both available and relatively inexpensive. Requirements would include an atomic absorption/flame emission spectrophotometer for Ca, K, Mg, Fe, Cu, Mn, Zn, and possibly Mo, and a colorimeter for P, N and S.

FOLIANT ANALYSES

In situations where there is not a reliable soil test, the reclamation worker can resort to tissue analysis. As with simple observation of deficiency symptoms, tissue analysis will provide an after-the-fact diagnosis of a current problem; however, it will enable the reclamationist to correct the situation by next season. Examples of the critical levels of elements in three plant species are shown in Table 3. In some cases the reclamationist may also want to calculate element ratios such as P/Fe, since elements such as these often interact both in the soil and the plant.

Table 1

NUTRIENT DEFICIENCY SYMPTOMS FOR SELECTED PLANTS

Element (absorbed as)	Functions in Plant Growth (mobility)	Deficiency Symptoms
N ($NO_3,NH_4{}^+$)	Constituent of protein and chlorophyll promotes vegetative growth, mobile	Chlorosis initiated on older leaves
P ($H_2PO^-{}_4,HPO_4{}^{-2}$)	Biochemical energy transformations (ATP) constituent of ribonucleic acids, mobile	Purpling of young plant, general stunted appearance
K (K^+)	Carbohydrate metabolism and translocation, protein synthesis, enzyme activator stomatal movement and water relations, mobile	Chlorosis on margins of older leaves
S ($SO_4{}^{-2}$)	Constituent of some amino acids, coenzyme A, increases oil content of crops, related to cold resistance, part of nitrogenous enzyme system involved in N fixation, relatively immobile	Uniformly chlorotic plants, stunted, thin stemmed
Mg (Mg^{+2})	Constituent of chlorophyll, related to P metabolism, plant respiration, mobile	Interveinal chlorosis on older leaves
Ca (Ca^{+2})	Necessary for meristematic development, membrane integrity, immobile	Failure of terminal bud to develop
B ($H_3BO_3,B_4O_7,{}^{-2}$)	Carbohydrate translocation, P metabolism, formation of growth hormones such as IAA, immobile	Chlorosis of younger leaves, internal breakdown of storage organs such as tubers
Fe (Fe^{+2},Fe^{+3})	Activator of several enyzme systems, chlorophyll synthesis, immobile	Interveinal chlorosis on new leaves
Mn (Mn^{+2})	Activator of enzymes concerned with carbohydrate metabolism, photosynthesis, immobile	Interveinal chlorosis on new leaves
Cu (Cu^{+2})	Enzyme activator, photosynthesis, immobile	Chlorosis, distortion of younger leaves
Zn (Zn^{+2})	Enzyme activator, immobile	Initially as an interveinal chlorosis on younger leaves followed by a large reduction in shoot growth, rosetting
Mo ($MoO_4{}^{-2}$)	N fixation, assimilation, protein synthesis	First as interveinal chlorosis, with legumes the same as N deficiency

Table 2

COMMONLY USED SOIL TEST EXTRACTANTS

Element	Extractant	Conditions
N (NO$_3$ $^-$ form)	H_2O	Leaching not significant
(Total N)	Kjeldahl digestion	Long-term N availability required
P (orthophosphate)	Bray's P_1 (.03 NH_4f in .025 N HCl.)	Acid to neutral soils with low to medium cation exchange capacities
	Olsen's 0.05M $NaHCo_3$ method pH 8.5	Both calcareous and non-calcareous soils
	Mehlich's dilute acid method (0.05N HCl and 0.025 N H_2SO_4)	Acid, highly weathered soils
K, Ca, Mg (exchangeable)	Neutral 1.0 N Ammonium acetate	Broad application
S ($So_4{}^{-2}$)	0.1 M $CaCl_2$ Ca (H_2PO_4), .05M $NaHCO_3$ (pH 8.5)	To obtain H_2O soluble $SO_4{}^-S$. To obtain adsorbed $SO_4{}^-S$.
B	Hot water	Soils not subject to intense leaching
Fe, Cu, Mn	0.1 N HCl	To extract organic plus forms held in organic matter
Zn	Chelates such as D T P A, E D T A	

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B	Hot water	Soils not subject to intense leaching
Fe, Cu, Mn	0.1 N HCl	To extract organic plus forms held in organic matter
Zn	Chelates such as D T P A, E D T A	

Table 3
SOME SELECTED CRITICAL LEAF TISSUE CONCENTRATIONS

Element	Alfalfa	Oats	Orchard grass
N	-	1.0	2.4
P, %	0.15	0.1	0.2
K	1.0	1.1	2.0
Ca, %	0.6	0.1	-
Mg, %	0.2	0.1	-
S, %	0.2	0.1	0.1
B, ppm	15	5	-
Mn, ppm	10	10	-
Zn, ppm	10	20	-
Cu, ppm	6	3	-
Mo, ppm	0.2	0.1	-
growth stage	early bloom	4-6 weeks	3-4 weeks

Tissue analysis can provide only a rough tool to establish the nutrient status of plants grown for reclamation purposes. Comparison with published critical values is hazardous since nutrient concentrations can change rapidly depending on the stage of growth. Tissue nutrient contents are useful in comparing treatment effects in field or controlled environment studies. Walsh and Beaton (1973) include several chapters on tissue analysis.

FERTILIZERS

Once the fertility requirements of the soil has been established, the next step is to determine the most appropriate method of supplying deficient nutrients. Usually, the most effective and simplest method is to add chemical fertilizers. The main exception to this statement could be N. It would seem to make sense to use symbiotic N fixing organisms whenever possible, because N requires the most energy to manufacture (N, P_2O_5, K_2O requires 77.5, 14 and 9.7 MJ/kg, respectively) and is more expensive than either of the two other macronutrients, P and K. The following discussion is limited to fertilizer nutrient sources. However, alternative nutrient sources, especially legumes, should be seriously considered in reclamation work.

TYPES OF FERTILIZERS

There is a wide range of fertilizers available today, which allows considerable flexibility in the form of the nutrient applied and in the ratios of the three macronutrients and S. By law, manufacturers must state a minimum guarantee of the plant nutrient content of fertilizers in terms of N, P_2O_5 and K_2O. The ratio of these nutrients in the fertilizer purchased should depend on the requirements of both the soil and the crop. For example, one might select a fertilizer with a 2-1-1 ratio for grasses or 1-2-2 for a stand of forages dominated by legumes. The trend in recent years has been to higher analysis fertilizers, motivated by the need to reduce the fixed costs of bagging, transporting and distributing the finished product.

The properties of five types of fertilizer will now be discussed.

Nitrogen - Two N sources, urea (46-0-0) and ammonium nitrate (34-0-0) make up the bulk of the N sold in western Canada. Most of the new fertilizer plants are designed to produce the less energy-requiring urea, rather than ammonium nitrate. Currently there is a cost differential of slightly over 10% in favour of urea. Urea is not ideal in all circumstances, however. It hydrolyzes rapidly to NH_3 which can be lost as a gas (especially from calcareous soils), or it can be toxic to plants; consequently, greater care is required in its use.

Because N tends to be quite mobile in soils and is easily lost, considerable research has developed new methods of reducing N losses. One example is sulphur-coated urea, a slow release fertilizer (Sheard, 1975). Molten S, which is coated on the urea prill, mostly oxidizes before the urea-N can diffuse out into the soil. The release of N can be controlled from two months to two years or more by this method. Other slow release fertilizers include osmocote and urea-formaldehyde.

A second example is the use of nitrification inhibitors to delay the nitrification of NH_4-N to NO_3-N. Research in the U.S. has shown two materials, N-Serve [2-chloro-6-trichloro methyl pyridine] and ATC (4-amino-1,2,4-triazole), to be effective nitrification inhibitors. Work at U.B.C. by Guthrie and Bomke (In Press) has indicated that N-Serve, because of its volatility, is not as effective in coarse textured soils as is ATC. ATC was shown to inhibit nitrification to some extent for up to three months when applied at a rate of 1 kg/ha with band applied urea. It was ineffective with broadcast urea.

Phosphorus - Because of its high water solubility, high P content, ease of handling and application, and relatively low cost, 0-46-0 triple super phosphate [$Ca(H_2PO_4)_2$] is currently the most popular P source. Other P sources include 0-20-0 (super phosphate) and rock phosphate. The latter has a low P content relative to triple super phosphate and is slightly soluble P source which can be used only on acid soils.

Potassium - The main source of K is KCl, 0-0-60. This is a high analysis and economical source of K. Most mine waste materials would require considerably less K than N or P.

Sulphur - The ready availability and economy of granular S in western Canada plus its high analysis (90 + % S) make it an ideal source of S. It can either be added singly or blended with N-P-K fertilizers.

Mixed Fertilizers - The above mentioned single nutrient fertilizers may be blended to produce complete or compound fertilizers. Fertilizers with ratios high in N and P (e.g. 3-4-1) should be appropriate for mine wastes, if there is no soil test information available. Another class of compound fertilizers is the ammonium phosphates such as monoammonium phosphates (11-55-0) and diammonium phosphate (18-46-0). These materials may be quite valuable in reclamation work because of their high proportions of N and P.

FERTILIZER CHARACTERISTICS

The proper use of any tool requires that its characteristics be understood. This section summarizes some of the relevant characteristics of fertilizers. As can be seen in Table 4, NH_4-N sources are significant producers of acidity. This effect would develop quite rapidly in coarse textured and poorly buffered mine wastes. Phosphorus, K and NO_3-N fertilizers have little effect on soil pH.

A second important property of fertilizers is expressed in terms of their salt index (Table 5). Fertilizers with a high salt index (N, K

Table 4

ACIDITY OR BASICITY OF COMMONLY USED FERTILIZERS

Material	% N	kg of pure $CaCO_3$ Per kg of N	kg of pure $CaCO_3$ Per 100 kg of Material
Ammonium sulphate	21	5.4	110
Urea	46	1.8	84
Ammonium nitrate	34	1.7	59
Ammonium phosphate	11	5.9	65
Calcium nitrate	15	1.4 B	20 B*
K C 1 (60-60)	0	0	0
Triple superphosphate	0	0	0

*B = indicates that the material is a base former in the soil.

Table 5

SALT INDEX OF SOME COMMON FERTILIZER MATERIALS

Material	Analysis (%)	Salt Index Per Equal Weight of Material*	Salt Index Per Unit of Plant Material
Ammonium nitrate	34	104.7	3.0
Ammonium sulphate	21	69.0	3.2
Urea	46	75.4	1.6
Calcium nitrate	15	65.0	4.2
K C 1	60	116.3	1.9
Triple superphosphate	45	10.1	0.2

*$NaNO_3$ = 100

sources) require care if they are being placed with the seed or are applied in contact with plant tissue. High salt concentrations around seedlings or roots give rise to high osmotic pressures which increases the plant's difficulty in acquiring water. The Salt Index is related to another property of fertilizers, namely solubility. P fertilizers are relatively insoluble when applied to the soil, resulting in minimal salt content in the soil solution as compared to the soluble N and K fertilizers.

The final property to be discussed, hygroscopicity, relates to the storage characteristics of fertilizers. Hygroscopicity is the tendency of salts to adsorb water whenever the vapour pressure of moisture in the air exceeds that of a saturated solution of the salt. Hygroscopicity increases in the following order: ammonium phosphate < potassium chloride < urea < ammonium nitrate < calcium nitrate. This property causes the caking and hardening of bagged fertilizer which, although not usually a problem for P or K fertilizers, can be a problem for improperly stored N fertilizers.

RATES AND METHODS OF APPLICATION

Most experiments on disturbed lands have used fertilizer rates similar to those recommended for infertile agricultural soils. These rates may be inadequate since some mine wastes are essentially devoid of N and may fix applied P into unavailable forms. Higher rates may, therefore, be required. If a legume is part of the seed mix, N rates should be reduced to allow the legumes an opportunity to compete with grass components of the mix. Trees used in revegetation will likely have a lower fertility requirement than herbaceous species. Growth rates may be lower and mycorhizal relationships on their roots may enable them to acquire relatively unavailable forms of P.

The method of application depends heavily on the type of area to be fertilized. A level tailings pond for example would be quite amenable to a broadcast application followed by incorporation of fertilizer. This may be beneficial prior to the seeding of perennial species, since P, K, and lime are relatively immobile in the soil and will not descend more than 5 cm below the soil surface following a topdressing. On rough or rocky terrain the fertilizer will likely have to be applied without the benefit of incorporation. Established forages are usually successful in obtaining adequate P and K from surface applications, although nutrients in a dry soil zone will be at least temporarily unavailable.

Foliar fertilization is not a viable alternative in reclamation work except in the case of micronutrients. The cost of transporting bulky liquid fertilizers, the high costs of highly soluble grades of fertilizers required, and the difficulties of supplying adequate N, P and K without damaging the foliage all severely limit the usefulness of foliar fertilization with macronutrients, except possibly in intensive horticultural production.

In summary, N and P and occasionally K fertilizers are valuable tools in revegetation work. It should be possible to build up the available pool of P and K, although long-term N fertility may be a problem. The solution may be in the use of leguminous species in seed mixes or perhaps the addition of nitrogenous organic amendments. This will be discussed in more detail in the next section. For a more complete discussion of fertilizers, consult the textbook entitled Soil Fertility and Fertilizers by Tisdale and Nelson (1975).

The cost of fertilizers may be as little as 1/100 of the total cost of reclamation. It is, therefore, important to augment the fertility of the material to be reclaimed in the initial stages of the vegetative process in order to insure that the investment of reclamation is protected. Also, because of the other costs involved in reclamation, the precision required in agricultural soil testing programs may not be necessary in reclamation. The site-specific nature of most projects will also dictate this.

SOIL AMENDMENTS

A soil amendment is any substance such as lime, sulphur, gypsum or organic materials which is used to alter the properties of the soil, generally to make it more productive. The term usually does not include highly concentrated nutrient sources such as fertilizers.

ORGANIC AMENDMENTS

Organic materials may or may not have beneficial effects on the available nutrient supply in the soil. The main determining factors include the C/N ratio and the physical state of the material. When an organic material is added to the soil, the microbial population rapidly increases in response to the increased substrate. If the material is well endowed with N relative to C, a net release of N into the soil mineral N pool will occur. On the other hand, a large amount of C relative to N (wide C/N) would tie up or immobolize soil N. A C/N > 30 will likely result in N immobilization, and one less than 20 in N mineralization. Some organic materials and C/N ratios are given below:

poultry manure	7
well rotted barnyard manure	20
clover residues	23
grain straw	80
sawdust	400

Any material with an N% < 1% will likely immobolize N, while a material with an N% > 1.5-1.7 will mineralize N. A wide C/N ratio can be reduced by the addition of N fertilizer to the material. The rate of breakdown is also dependent upon the particle size of the material. For example, smaller particles such as sawdust will decompose more quickly than wood chips.

In addition to the possible fertilizer value, some organic amendments may have other beneficial effects when incorporated into soils. These include:

a. increasing the water holding capacity of the soil;

b. increasing the cation exchange capacity and the nutrient holding ability of the soils;

c. improving the structure and aeration of fine textured soils.

Since the materials to be revegetated are often coarse textured and may have a high percentage of coarse fragments, a. and b. above are especially important in reclamation. Greenhouse experiments at U.B.C. demonstrated the beneficial effects of poultry and cow manures on severely acid sulphide tailings.

Mulches are unincorporated organic materials used for stabilizing soils, conserving moisture, moderating temperature fluctuations, controlling weeds and reducing seed loss prior to germination. Mulches may be locally available waste products such as forest by-products, or commercially available mulches such as those available as by-products from grass seed production. In order to be effective, minimum rates of 1100 to 1700 kg/ha of wood wastes, or 2200 to 4500 kg/ha of straw or hay are required. Additionally, an effective mulch must stay put, must not impede the infiltration of water or the diffusion of gasses into or out of the soil, or have a deleterious effect on the plant cover. Because of the bulky nature of mulches, it is best to use locally available materials such as wood wastes in B.C. For further information the reader is referred to Plass (1978) and Kay (1978).

INORGANIC AMENDMENTS

Limestone is the most common inorganic amendment. Acid materials such as some sulphide tailings could benefit from lime addition as would exposed acid subsoils. The feasiblity of liming depends on the location of the site to be revegetated and the amount of lime required. For example, we determined in a greenhouse study that short-term neutralization of acid sulphide tailings from a northern Vancouver Island mine required nearly 50 t/ha. Obviously it would be impractical to try to improve these tailings by liming.

Highly calcareous materials can also present problems in P and micronutrient availability. Sulphur may be used as a soil amendment to acidify calcareous materials as a result of the following reaction:

$$S + 3/2\ O_2 + H_2O \xrightarrow[\text{spp}]{\text{Thiobacillus}} H_2SO_4$$

One kg of S is equivalent to approximately 3 kg of $CaCO_3$.

I have attempted to outline the methods of assessing the fertility of disturbed lands, and have described the fertilizers and soil amendments available for improving tailings productivity. Both fertilizers and soil amendments can play a role in reclamation work, depending on the economics, and the soil factors which require modification. In all cases, practices which encourage short-term rapid growth at the expense of long-term vegetative stability should be avoided.

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DISCUSSION RELATED TO A. BOMKE'S PAPER

Niel Duncan - Energy Resources Conservation Board, Alberta: With the possibility of a coal-fired station near Cache Creek, what is the chance of using fly ash as an inorganic amendment?

Answer: I'm sorry. I haven't had any experience with fly ash.

A. Reed, Afton Mines Ltd.: Would a low grade coal such as the Hat Creek deposit qualify as an organic amendment?

Answer: Well, let's look at what it might be used for. I don't think that it would be suitable as a mulch material. It doesn't have the characteristics that I'd like to see in a mulch, so we could rule that out. Now, whether it has any useful significance as an incorporative material, I can't say. Some of the coals tend to be resistant to decomposition, and some do not readily release nutrient such as nitrogen. I don't know specifically about any tests at Hat Creek. Perhaps the (Acres) people could tell us.

Acres: I think I can answer your question. There are far too many of the so called order of metals and elements in the Hat Creek coal to ever dare consider (Editor: we regret that the remainder of this answer was not recoverable from the taping).

Zig Hawthorn - B.C. Hydro: We have tried growing vegetation on waste coal at Hat Creek. It does grow, but it's difficult. Topsoil on the waste coal does improve the vegetative success rate, but again growth is difficult to achieve. We haven't tried it the other way around, where we add a little bit of coal to a lot of soil, so we can't really answer that question.

Questioner Unidentified: (Distorted Recording. Question related to the properties of selenium and its effect on foraging animals on reclaimed land.)

Answer: I think it is reasonably clear that selenium is not an essential element for plants. It is taken up depending upon how much of it is present in the soil. I don't know of any work on a field scale where people have taken selenium and applied it in order to increase the selenium content of forage. I think it is a very risky proposition. It's more likely that we will be successful by some sort of injection, or perhaps even a mineral block of something. I might also add that selenium deficiencies seem to be accented by sulphur fertilization. So, if it is seen that sulphur gives a good response and they really chuck the sulphur on, this can actually compete with selenium uptake and decrease the value of that material as a forage by creating problems such as White Muscle Disease.

WASTE DUMP MANAGEMENT
FOR
RECLAMATION, STABILITY
AND
EROSION CONTROL

Chairman of the Morning Session

Thursday, March 6, 1980

by

D.M. Galbraith

Ministry of Energy, Mines and Petroleum Resources

STABILITY AND ECONOMIC CONSIDERATIONS IN DUMP DEVELOPMENT

(PAPER NOT AVAILABLE)

by

D. Campbell

Golder Associates

DISCUSSION RELATED TO D. CAMPBELL'S PAPER

Niel Duncan - Energy Resources Conservation Board, Calgary: Can you describe the types of equipment that were used in the inclined trench method?

Answer: I should get Tony Milligan to answer your question because Kaiser used the inclined bench method.

Tony Milligan (continues with the answer): You can operate with bulldozers on both the horizontal and the inclined bench methods. However, you may not work directly down the fall line; that is, you may work at an angle down the slope. It doesn't invalidate the amount of material you have to move, but if you move diagonally rather than directly down the slope it does change (increases) the distance that you have to transport the material. Kaiser feels that they can operate equipment on 2:1 slopes. They also operate large cultivating equipment on these slopes in order to prepare the surface prior to seeding and fertilizing.

Niel Duncan: I have a second question. With some of the dumps that are built by benching from the bottom, down, there are a series of benches right from the start, without having to rework at either the level bench or the inclined bench. How do the economics of that system compare to the other two?

Answer: First let me say that I would like to commend the B.C. Department of Mines for their enlightened approach to waste dump development in British Columbia. There are jurisdictions in North America that have precluded this type of waste dump development. They say that waste dumps must not be built on slopes of "less than 50". This is a blanket regulation. It does not take into account the height of waste dump you are going to build, the properties of the foundation, or the methods you are going to use to build it. Some jurisdictions also say that you cannot build a waste dump by end dumping from the crest. You have to start from the bottom and build up. Now, I see two disadvantages in building from the bottom up. First, is that you don't get this segregation of rock sizes on high waste piles that you get by end dumping from the crest, and therefore there is no drainage on the bottom. So, for a given dump configuration, it follows that building the waste dump pile from the bottom up may not provide the degree of stability that we get by end dumping. Don't misinterpret that comment. Provided the factor of safety is high enough above 1.0, the waste pile is not going to fail. It doesn't really matter whether the factor of safety is 2 or 1.7 or 1.5. Second, is the aspect of economics. We are mining in British Columbia in areas where there is very high topographic relief. If you're going to start operating an open pit mine in a mountainous area and part of your ore is up near the top of a ridge, that's where you have to start. If the regulations say that you cannot build the waste dump by end dumping, I can tell you right now that there are a number of ore bodies, whether they are ore metaliferous or whether it's coal mining, that the cost of hauling will kill the economics. The projects just won't go because the money isn't there. I think those types of regulations are unnecessary. However, I'd like to commend the B.C. Department of Mines for their independent look at this problem. I think that is the proper approach to take.

Questioner Unidentified: Is the height the distance from the crest of the dump to the original floor of the dump?

Answer: No, the height that we're looking at is the difference in elevation between the crest and the toe prior to failure. Now the cotangent of alpha also takes into account whatever natural slope there may be before the failure occurred. We haven't many data points on waste dumps.

Questioner Unidentified: (Distorted recording. The question related to number of data points.)

Answer: Six. The points all plot, I think, as close to a straight line, or as close to a curve as you could expect from field data. I think the data does give us a pretty good indication of what the potential danger might be beyond the toe of the dump.

Jim Meier - Byron Creek Collieries: I'm wondering if you have an optimum height where you don't get segregation.

Answer: I think that we're dealing with rock as opposed to soil. The degree of segregation is going to increase with the height of the dump. The median size of the particles at the bottom are going to be a function of dump height. That is, the larger the dump, the larger, probably, will be the median size particles. To answer your question, if you dump shot rock over a bank twenty to thirty feet high, you will get significant particle size segregation. The one example that I know is a consultant who lives in California. His name is Barry Cooke. Some of you may know him. Barry is a very practical guy, and if you have a real problem with a dam, especially if you're a contractor, you call Barry Cooke. I recall one job he had where that happened. It was an unexpected flood through a partially completed dam. Barry went out and tried a number of things to get the flows down so they could close the lower gates. One thing he did was to make up boulder necklaces. These were boulders which they drilled holes through and strung with cables. They picked up these necklaces and dropped them in the channel. The way Barry got those boulders was by quarrying rock and dumping it over a slope. The coarse stuff segregated out at the toe, and they selected the big pieces they wanted. As I recall, the bank was twenty or thirty feet high.

WATER QUALITY AND ITS CONTROL IN MINING AREAS

by

H. Howie

Waste Management Branch
Ministry of Environment

WATER QUALITY AND ITS CONTROL IN MINING AREAS

Normally, mining operations will cause some deterioration to the quality of the associated surface water and groundwater. However, with good mining practices, including careful control of mining discharges and proper reclamation, the resulting water quality can usually be made acceptable for discharge into the receiving environment. Control of water quality is the responsibility of the Pollution Control Section of the Waste Management Branch and the Regional Operations Division, acting under the jurisdiction of the Pollution Control Act and Regulations.

This control is accomplished with Pollution Control effluent Permits which authorize effluent discharges of a specified quantity and quality from mining operations, and which require regular monitoring to assure that such quality is being maintained. All effluent discharges from mining operations not authorized by Pollution Control Permits are illegal.

To guide the Director of Pollution Control in his assessment of effluent discharges from mining operations and in his granting of effluent Permits to authorize such discharges, the Pollution Control Board has issued the Pollution Control Objectives for the Mining, Smelting, and Related Industries of British Columbia. These Objectives are based on earlier (1973) Objectives which were reviewed and amended in 1979 to include experience gained with the earlier Objectives, and input from public meetings held in six centres around the province, and a public inquiry held in Victoria in 1978. (I have several copies of the amended Objectives on hand should anyone wish a copy, and if the limited supply is insufficient, I will take your name and address and send you a copy.)

I would now like to refer to Table IV and Table V of these amended Objectives which particularly relate to water quality. Table IV (Slide No. 1) outlines the receiving water control objectives which would

Slide No. 1/Table IV

B. DISCHARGES TO WATER
RECEIVING WATER CONTROL OBJECTIVES (1)

Parameter	Level
Dissolved oxygen	Not less than 90% of the seasonal natural value
Temperature	To be within 1°C of the natural level
Turbidity	Not more than 5 JTU above the natural value
Floatable solids	None
pH	No change
Toxicity (96 hr static bioassay)	Below detectable limit
Colour	No change
Aesthetics	No decrease
Alkalinity (2)	Not less than 20% natural value
Chloride	Not more than 25 mg/L
Fecal coliforms (3)	Not to exceed Ministry of Health standards

(1) Applicable outside the initial dilution zone.

(2) Not applicable to marine discharge.

(3) Applicable only when sanitary discharge is mixed with effluent.

normally apply to the neighboring stream, river, lake, or ocean and which, in turn, would normally be monitored in a manner that would determine the effect of the mining operations on this receiving environment. This monitoring would be one of the requirements of the effluent Permit, and normally would include regular monitoring of the neighboring stream(s) upstream and downstream of the mining operations, and the periodic reporting of such monitoring. The details of the required monitoring are site specific and are determined in the assessment process. Examples will be discussed later in this presentation.

Table V (Slide No. 2) outlines the objectives for the discharge of final effluents to marine and fresh waters. These objectives apply to the discharge of treated mine effluents to receiving waters, such as the effluent discharges from tailings ponds, settling ponds, or other treatment works to neighboring streams, etc., but which are not "closed-circuit", that is, totally recycled to operations. Each final effluent discharged from a mine-mill complex or a mine-cleaning plant complex is authorized by Permit, usually as one appendix of a comprehensive effluent Permit for the entire complex.

One requirement of this effluent Permit is normally the regular monitoring of the significant parameters of each separate discharge and the periodic reporting of such monitoring, some or all of which is transferred to the Government computer bank. At intervals, these data are retrieved and statistically analyzed and serve as part of a Permit review process which results in an amended Permit and which, in turn, may require changes to the pollution control treatment, Permit monitoring, etc.

I would like to mention that Table V Objectives give a range of values for each parameter, whereas the earlier (1973) Objectives presented three levels for each parameter. The philosophy behind the earlier Objectives was to recognize existing operations, many of which required upgrading to move from Level C, through Level B, to the desirable Level A. The philosophy behind the present Objectives is to present a generally acceptable range for each parameter, but to allow the choice of each parameter value to be site specific based on the assimilative capacity of the environment and other considerations. However, a modified Table V, which includes "Old Level A" (Slide No. 3) shows that the "Old Level A" is usually similar to the low end of the "new range".

I would now like to briefly review examples of several different types of mining operations in British Columbia, and indicate their methods of effluent control and their required monitoring programs.

1. Western Mines Ltd. is an example of a base metal underground mine and concentrator with discharge of tailings slurry at depth to a lake, and with collection and treatment of minewater and surface runoff by settling ponds. The regular monitoring required by Permit is as follows:

    - the tailings slurry is monitored for flow, pH, suspended solids, dissolved sulphate, total cyanide, residual chlorine, and both total and dissolved metals (Cu, Pb, Zn);

    - the receiving water (Buttle Lake) is biologically monitored and fish tissue is analyzed for metals;

    - the settling ponds supernatants and nearby streams are monitored for pH, suspended solids, dissolved sulphate, total cyanide and total mercury, and dissolved metals (Cu, Pb, Zn, As, Cd).

2. Utah Mines Ltd. is an example of a base metal open pit mine and concentrator with discharge of tailings slurry at depth to the ocean, and with collection and treatment of minewater. The regular monitoring required by Permit is as follows:

    - the tailings slurry is monitored for flow, pH, suspended solids, temperature, total cyanide and total mercury, dissolved metals

Slide No. 2/Table V

OBJECTIVES FOR THE DISCHARGE OF FINAL EFFLUENTS TO MARINE AND FRESH WATERS

Parameter	Range	
(mg/L dissolved in effluent unless otherwise stated) (5)		
Total suspended solids (1) (2)	25	75
Total dissolved solids	2,500	5,000
Toxicity (96 hr LC 50 static bioassay) (3)	100%	80%
pH (pH Units)	6.5-8.5	6.5-10
Radioactivity: (6)		
Gross Alpha pCi/L	10	100
Radium^{226} pCi/L (dissolved in effluent passing through a 3 μm filter)	less than 10	
Specific elements and compounds:		
Aluminum (Al)	0.5	1.0
Ammonia (as N)	1.0	10.0
Antimony (Sb)	0.25	1.0
Arsenic (as trivalent As)	0.05	0.25
Arsenic (total dissolved)	0.10	1.0
Cadmium (Cd)	0.01	0.1
Chromium (Cr)	0.05	0.3
Cobalt (Co)	0.5	1.0
Copper (Cu)	0.05	0.3
Cyanide (as CN)	0.1	0.5
Fluoride (F)	2.5	10.0
Iron (Fe)	0.3	1.0
Lead (Pb)	0.05	0.2
Manganese (Mn)	0.1	1.0
Mercury (Total) (Hg) (4)	Nil	0.005
Molybdenum (Mo)	0.5	5.0
Nickel (Ni)	0.2	1.0
Nitrite/Nitrate (as N)	10.0	25.0
Phosphate (Total P biologically available in effluent)	2.0	10.0
Selenium (Se)	0.05	0.5
Silver (Ag)	0.05	0.5
Uranyl (UO_2)	2.0	5.0
Zinc (Zn)	0.2	1.0
Oil and Grease (Total)	10.0	15.0

(1) Not applicable to approved direct discharge of tailings solids.
(2) Variances may be allowed during periods of excess runoff.
(3) Bioassay on salmonid species.
(4) Natural background concentration will be assessed.
(5) Analysis for Total Elements in tailings may be required prior to and during operations and the Director would give consideration to this information when issuing a permit.
(6) To apply to operations where the objective is not the mining of radioactive ores.

Slide No. 3/Table V

OBJECTIVES FOR THE DISCHARGE OF FINAL EFFLUENTS TO MARINE AND FRESH WATERS

Parameter	Range		"Old" Level A
(mg/L dissolved in effluent unless otherwise stated) (5)			
Total suspended solids (1) (2)	25	75	50
Total dissolved solids	2,500	5,000	<2,500
Toxicity (96 hr LC 50 static bioassay) (3)	100%	80%	100%
pH (pH Units)	6.5-8.5	6.5-10	6.5-8.5
Radioactivity: (6)			
Gross Alpha pCi/L	10	100	-
Radium^{226} pCi/L (dissolved in effluent passing through a 3 μm filter)	less than 10		-
Specific elements and compounds:			
Aluminum (Al)	0.5	1.0	0.5
Ammonia (as N)	1.0	10.0	0.5
Antimony (Sb)	0.25	1.0	0.25
Arsenic (as trivalent As)	0.05	0.25	
Arsenic (total dissolved)	0.10	1.0	0.05
Cadmium (Cd)	0.01	0.1	0.005
Chromium (Cr)	0.05	0.3	0.05
Cobalt (Co)	0.5	1.0	0.10
Copper (Cu)	0.05	0.3	0.05
Cyanide (as CN)	0.1	0.5	0.10
Fluoride (F)	2.5	10.0	2.50
Iron (Fe)	0.3	1.0	0.30
Lead (Pb)	0.05	0.2	0.05
Manganese (Mn)	0.1	1.0	0.05
Mercury (Total) (Hg) (4)	Nil	0.005	0.001
Molybdenum (Mo)	0.5	5.0	0.5
Nickel (Ni)	0.2	1.0	0.3
Nitrite/Nitrate (as N)	10.0	25.0	10.0
Phosphate (Total P biologically available in effluent)	2.0	10.0	2.0
Selenium (Se)	0.05	0.5	0.05
Silver (Ag)	0.05	0.5	0.10
Uranyl (UO_2)	2.0	5.0	2.0
Zinc (Zn)	0.2	1.0	0.5
Oil and Grease (Total)	10.0	15.0	15.0

(1) Not applicable to approved direct discharge of tailings solids.
(2) Variances may be allowed during periods of excess runoff.
(3) Bioassay on salmonid species.
(4) Natural background concentration will be assessed.
(5) Analysis for Total Elements in tailings may be required prior to and during operations and the Director would give consideration to this information when issuing a permit.
(6) To apply to operations where the objective is not the mining of radioactive ores.

(Cu, Mo, Cd, Cr, Co, Fe, Pb, Mn, Ni, Zn and As) and is also monitored by bioassay tests;

- the receiving marine environment is monitored comprehensively for bottom sediment distribution, suspended sediment distribution, and water monitoring for pH, temperature, dissolved oxygen, turbidity, suspended solids, alkalinity, salinity, and dissolved metals (Cu, Mo, Mn, As and Hg);

- the receiving marine environment is monitored comprehensively with both plant and animal biological monitoring required;

- the surface runoff water (including pit water) is comprehensively monitored for pH, temperature, suspended solids, dissolved solids, turbidity, alkalinity, colour, hardness, dissolved oxygen, sulphates, nitrates, and dissolved and total metals (Fe, Cd, Cu, Co, Cr, Mo, Pb, Zn, Ni and Mn).

3. Cominco Sullivan Mine is an example of a base metal underground mine and concentrator with discharge of tailings slurry to tailings ponds, and with collection and treatment of the overflow from the tailings ponds, minewater, and surface runoff before discharging the treated effluent to a stream. The regular monitoring required by Permit is as follows:

   - the wastewater treatment plant discharge is monitored for flow, pH, suspended solids, turbidity, total phosphate, ammonia (N), dissolved fluoride, oil and grease, and both total and dissolved metals (Fe, Pb, Zn, As) and total Cu, Cd, Mn, and CN;

   - the receiving water (St. Marys River) is monitored chemically and biologically both upstream and downstream of the treatment plant.

4. Gibralter Mines Ltd. is an example of a base metal open pit mine and concentrator with discharge of tailings slurry to a tailings pond, with recycle of pond supernatant to operations, and with collection and treatment of seepage and surface runoff. The regular monitoring required by Permit is as follows:

   - the flows of tailings slurry, of tailings pond supernatant, of seepage pond supernatant recycled and discharged to Cuisson Creek, and of Cuisson Creek are measured;

   - the seepage pond supernatant and the receiving water (Cuisson Creek) are monitored for pH, suspended solids, dissolved metals (Cu, Mo, Fe), $SO_4^{=}$, and total CN. A bioassay is required on the supernatant prior to its discharge to Cuisson Creek.

5. Fording Coal Ltd. is an example of an open pit coal mine and cleaning plant with discharge of tailings slurry to a tailings pond, with recycle of pond supernatant to operations, and with collection and treatment of contaminated surface runoff including pit water. The regular monitoring required by Permit is as follows:

   - the tailings slurry and tailings pond supernatant are monitored for flow, pH, suspended solids, and total solids;

   - the decants from the surface runoff settling ponds and pitwater are monitored for flow, pH, suspended solids, total solids, and oil and grease;

   - the receiving water (Fording River) is monitored upstream and downstream for pH, suspended solids, total solids, $SO_4^{=}$, acidity, alkalinity, turbidity, organic carbon, oil and grease, nitrites/nitrates, and dissolved Fe and Mn.

A comparison of monitoring in the preceding examples shows that the recieving effluent environment around base metal mines is normally monitored for pH, suspended solids, dissolved metals (normally present in the ore), and total CN (when used); when the tailings slurry is discharged at depth to a lake or ocean more extensive metal monitoring and biota monitoring are required. The receiving effluent environment around coal mines is normally monitored for pH, suspended solids, nitrates, and certain other parameters (which normally need to be monitored for a short time and then discontinued). In summary, the required water monitoring in the receiving environment around B.C. mines is normally less when tailings supernatant is totally recycled to operations or when tailings supernatant, surface runoff, etc. is treated.

In conclusion, I would like to mention two items of interest which are ongoing at the present time. The first item is a cooperative industry-government study on the decomposition products of ANFO explosives, which I believe will complement similar studies being carried out separately by some of the mining companies in British Columbia. The industry-government study particularly relates to NH_3, nitrites, and nitrates and is being done by Fording Coal Ltd., the Water Investigations Branch, the Waste Management Branch, and the Regional Operations Division (the latter three being in the Ministry of Environment) and is being carried out at the Fording Coal Minesite.

Interim results would indicate that fairly significant amounts of nitrates appear to be produced and are to be found in certain runoff streams. I would like to advise that the Water Investigations Branch intends to expand this study to include a review of existing water quality information around mining areas and to determine the amount of explosives that B.C. Mining Companies used in 1979.

The second item that I wish to mention is the ongoing preparation of "Guidelines for the Design and Operation of Settling Ponds Used in Mining Areas" which should be useful for both operating and developing mines in controlling the level of suspended solids in the surface run-off streams. I have prepared the first draft guidelines, have circulated them to various Agencies, Consultants, etc., and am now starting to prepare the final Guidelines for the Director's consideration and approval. I hope that they will be published in the reasonably near future.

DISCUSSION RELATED TO H. HOWIE'S PAPER

C. Guarnaschelli - Hardy Associates Ltd.: I think you mentioned the assimilative capacity of your system. I'm thinking of your field techniques that are represented by a range of values based on assimilative capacity. I have two questions on that: 1) Because I've been involved in past years inthe study of assimilative capacity, have you defined any terms like "oxygen volume", "BOD", and things like that; and 2) if I as a consultant have my company ask me to define "assimilative capacity system", would your department in the provincial government be able to assess my presentation, within reason, on a site-specific basis?

Answer: I think the answers to your questions are "yes", particularly so with respect to your second question. Yes, we would, and we do do such things. And that is normal now. It's now a site-specific and assessment type business.

WASTE DUMP DEVELOPMENT
AT
KAISER RESOURCES LTD.

by

Ricci Berdusco

Kaiser Resources Ltd.

WASTE DUMP DEVELOPMENT AT KAISER RESOURCES LTD.

INTRODUCTION

The development of waste dumps has continued at Kaiser Resources Ltd.'s coal mining operation in southeastern British Columbia since 1967. The design and location of waste dumps are important criteria in the development of efficient mine and reclamation plans. With increased mining activity in the whole region and more complicated and diverse mining ventures being planned, a mining scheme which considers the impact of the mine on all aspects of the environment and also incorporates a reclamation schedule is becoming increasingly important. Such an assessment is underway on a proposed mine in the Greenhills area approximately 22 miles (35 km) north of Sparwood.

The present mine is located on Harmer Ridge approximately 3 miles (5 km) east of Sparwood. The Harmer mine is situated on the northeastern rim of the Crows Nest Coal Basin, a large topographical feature 30 miles (48 km) long and 12 miles (19 km) wide. In this area there are 12 mineable seams within a 2,500 foot (760 m) stratigraphic sequence. The coal seams vary from 5 feet (1.5 m) to 50 feet (15 m) in thickness and occur at elevations of between 3,500 feet (1070 m) and 7,500 feet (2290 m).

The rock units which comprise the overburden consist mainly of sandstones and siltstones with some mudstones, carbonaceous shales, and conglomerates. The coal proposed for mining is mainly medium-volatile bituminous coal with some high-volatile bituminous seams in the upper stratigraphy. All seams are low in sulphur content.

The mining method used to produce the bulk of the coal is shovel-truck mining, operating 15 and 25 cubic yard shovels and end-dump trucks ranging from 100 ton to 350 ton capacity. The large volumes involved in the operation, therefore, produce large dumps which grow to designed size very quickly. The steep topography and high elevation of the mine site demands a dump design that ensures stability, concomitant with careful construction to ensure safety. It must also show a commitment to land reclamation and the avoidance of environmental damage.

DUMP DESIGN

The first stage of dump design involves selecting a dump site. In the mountainous terrain of the Elk and Fording River Valley areas, this generally necessitates dumping stratigraphically below the footwall of the lowest coal seam being mined. Where the coal seams are dipping, a wrap-around dump configuration is used on the slopes below the footwall. In areas where the seams are generally flat or slightly synclinal and where several seams are to be mined, material is hauled downhill to reach the footwall of the lowest seam. Following the general site selection, the dump is designed based on the following parameters: stability, economics, and environmental impact.

STABILITY

The importance of dump stability is obvious. The potential costs involved with a failure become so large that, in all cases, a consultant is retained to study the dump proposals in order to ensure that the probability of a slide is remote. Consultants examine the proposals on the basis of dump material, size of the dump, topographic surface covered by the dump, consistency of the foundation, and relevant hydrological parameters.

The blasting of competent sediments prior to loading and end-dumping by large equipment produces a somewhat coarse dump which undergoes some natural segregation during actual dumping. The toe area of the dump is coarser than the upper slope, thus preventing a build up of pore pressures that could cause dump instability. The foundation of a proposed dump is also tested for possible instability; areas with known potential hydrological problems are avoided.

ECONOMICS

Another consideration in designing a dump is to make its construction as economical as possible. Shortening the haul lengths to reduce haulage and dumping costs are prime objectives. The amount of material to be rehandled during reclamation of a completed dump is also forecast.

ENVIRONMENTAL IMPACT

Environmental considerations are interrelated with the stability and economic parameters of dump design. Stream valleys and heavily wooded areas are avoided because of the possible instability created by wet, weak foundations. In addition, major alterations of stream valleys caused by dumping could result in other potential environmental problems. For example, the siltation of streams by drainage from a dump slope must be avoided due to potential fisheries damage and the detrimental effects on water quality. The aesthetic impact of a large dump in an exposed area is also a governing factor in dump design and dump site selection.

When all the factors have been weighed and recommendations from the geotechnical and environmental studies have been implemented, the final dump design can be incorporated into the mine plan and application can be made for the appopriate Mine permit. The next step is dump construction.

DUMP CONSTRUCTION

Dump construction involves several procedures which are closely monitored to avoid problems during and after construction.

The first step is site preparation, this could involve prelogging or brushing, trenching to avoid siltation, or berming of the toe area to prevent large materials from advancing too far down the slope. On Harmer Ridge, most of the major wrap-around dumps have been prelogged and the merchantable timber removed. The smaller Baldy Ridge mine has been brushed off as only small stands of lodgepole pine covered the dump area. Runoff from these areas is controlled by two large dams which retain the fines washed from the dumps. Since the dumps are constructed above eastward and northward flowing drainages, the runoff from the mine site can be treated quite effectively at the dam locations before leaving the mine property.

When site preparation has been completed and dumping has begun, it is important that common sense should prevail to ensure safe construction of the dump. Very fine materials which tend to slide and become unstable under load or saturation should be dumped along the outside ridge of the developing dump, or preferably in an alternative location where heavy traffic or any other cause for potential failure cannot jeopardize the dump. Whenever possible, dumps should not be constructed on areas covered by deep snow. The dump should also be monitored to detect abnormal movement, for dumps tends to settle, particularly on their outside edge. This deformation should be carefully examined for telltale signs of a possible failure. At Harmer Ridge, dump movement is minimal. The reasons for this are that because of the amount of equipment in operation multiple bench mining is necessary and two or more dumps are being constructed simultaneously. The lower dump tends to load the toe of the upper dump and thus stabilizes any settling tendency. Also, to provide for future mine developments on the ridge and the necessity to maintain eastward flowing drainages, narrow dumps were designed for this area. Narrow dumps tend to advance quickly and settle minimally.

As the dump nears completion, several modifications can be incorporated in the design. The first step, usually, is to free dump the whole area back to the pit limit. This releases dump maintenance equipment for use elsewhere and progressively shortens the haul length. When the pit limit is reached, the dumping is resumed in the initial development direction, but inclined upwards at an angle of 2% to 6%. The usual grade is 4% which, from an economic standpoint, provides the most suitable compromise between gain in dump elevation and the loss of truck performance. This final dump development is watched closely so that as much material as possible can be dumped over as short a distance as possible without jeopardizing the dump design.

When this step is completed the wrap-around dump is ready for resloping. The general dimensions of the dump lifts (without the final ramping) are 100 to 140 feet wide every 50 feet of elevation. Instead of the major dumps being designed in a wrap-around configuration, mining situations sometimes allow for construction of dumps onto the exposed footwall. This can occur where the footwall is less than 25°, but preferably less than 15° in dip. Generally such situations are limited by a lack of dump room, so the dumps are usually constructed with upward grades of 4% and with efficient use of all available room. The dumps are typically narrow (100 feet), except in very low-dip and synclinal situations where a wider profile is possible. The constructed dumps are then ready to be reclaimed.

DUMP RECLAMATION

Dump reclamation usually occurs after a short period but may be up to 5 years after completion. The final dump slope of 34°-36° still continues to settle during this dormant period, even with one or two lifts below it, and produces a profile of smaller benches which further aid the resloping task. There are two general configurations which result from resloping of the dumps. The first condition exists where the end-dumping has produced a long high slope. The angle of repose of the material (34°-36°) is reduced to 30° which is punctuated every 200 feet in elevation by a 20 foot horizontal berm. This results in an overall slope of 28.7°. In the areas where a 100 to 140 foot wide dump occurs every 50 feet, the slope between berms is reduced to 22.5° and berms of approximately 90 feet are left. This produces an overall slope of about 14°.

Depending on the type of material being dumped and on whether a 30° slope or a 22.5° slope is being created, D9 dozers are used to push material perpendicular to the proposed contour of the slope. This works ideally where the slope is being reduced to 22.5°; but where steeper slopes are required, the dozers have difficulty backing directly up slope. In this case, they turn and push parallel to the desired contour, which results in a steeper slope made up of many small benches. The benches retain moisture important to seed germination and plant growth. This growth spreads as the terraces slough off. It is important to provide for surface drainage when resloping. Features such as terraces, catchment ditches, and a rolling topography all prevent rapid runoff and retain water for short periods which promotes the development of good ground cover.

During the summer of 1979, high single-lift dumps constructed in 1969-70 were resloped in preparation for fall seeding. The largest dump, on Six-Mile Creek, required the handling of approximately 4,000,000 yd^3 of material back to a slope of 28°. The material was a combination of blasted rock and clay-rich overburden. The material could only be resloped to approximately 22° by direct downhill dozing, due to the soft nature of the material. Therefore, after the steepest grade had been attained by down-dip pushing, the dozers terraced the dump to a 28° overall slope by dozing parallel to the contour. The program in this creek valley progressed satisfactorily and demonstrated how the coarse material has accumulated at the toe of the dump. It also indicated the need for several major cross-berms in addition to the general terrace effect. These berms aided in seeding and harrowing.

Another dump that was resloped was situated in a steep section of Sawmill Creek, where the slope could not be reduced to less than 34° over most of the area. The dump was initially constructed over sandstone bluffs that formed a 34° face. As the face could not be cut back to create the proper angle and there was not enough material in the upper regions of the dump, terraces which could accommodate a small D7 dozer were constructed. After a terrace was completed, it was necessary to undercut part of it to provide enough material to construct the next bench. The result was a terraced section of stream valley sloping 34° at the top, down to approximately 28° at the toe. The terracing should prevent rapid runoff on the slope.

CONCLUSIONS

The examples of Six-Mile Creek and Sawmill Creek illustrate the planning of dump development and the potentially high cost of dump reclamation. Site selection and design of construction are two important decisions made in the life of a project, which are modified only slightly during construction. The costs of constructing the initial dump must be weighed against the costs of possible extensive resloping in order to ensure successful dump reclamation.

These considerations, along with sound design and construction, will simplify the task of reclamation - the final stage of waste dump development.

DISCUSSION RELATED TO R. BERDUSCO'S PAPER

The questions and answers are combined with those pertaining to C. Pelletier and D. Lane's papers. They are presented following D. Lane's paper.

WASTE DUMP DEVELOPMENT AT ISLAND COPPER

(PAPER NOT AVAILABLE)

By

C. Pelletier
Utah Mines Ltd.

ENVIRONMENTAL AND ENGINEERING CONSIDERATIONS FOR WASTE DUMP DESIGNS AT THE FORDING RIVER OPERATION

by

Dermot P. Lane

Reclamation Officer
Fording Coal Limited

ENVIRONMENTAL AND ENGINEERING CONSIDERATIONS FOR WASTE DUMP DESIGNS AT THE FORDING RIVER OPERATION

INTRODUCTION

Fording Coal Limited operates the Fording River coal mine located in southeastern British Columbia. The minesite, as shown on Figure 1, is within the medial range of the southern Canadian Rocky Mountains approximately 84 miles (136 km) north of the United States international border and 6 to 11 miles (9.8 to 17.5 km) west of the British Columbia/Alberta provincial border.

The Fording River Operations produce an average of three million tons of cleaned metallurgical coal per annum, primarily for export to Japan. Mining operations commenced in 1972 and are carried out on a basis of three eight-hour shifts, seven days per week. The operations employ both truck/shovel and dragline mining techniques in multiple seam pits. Shovels are in the 12 cubic metre range with trucks in the 120-ton to 170-ton size. The dragline is in the 60 cubic metre range. Total material moved annually is approximately 20 million bank cubic metres of waste and 4 million tons of raw coal.

DESCRIPTION OF MINE AREA

Fording's operation lies within the continental temperate climatic zone. Annual precipitation averages 85 cm, of which half occurs during the growing season. Temperature extremes range from -40°C in winter, to +35°C in summer. Table 1 gives the average climatic data recorded at the Fording River minesite from 1973 to 1977.

The area is described as the Englemann spruce - subalpine fir zone, with mining operations occurring from 1600 to 2500 metres above sea level. Vegetation cover on the valley bottom and lower slopes is

Figure 1

FORDING RIVER MINESITE LOCATION MAP

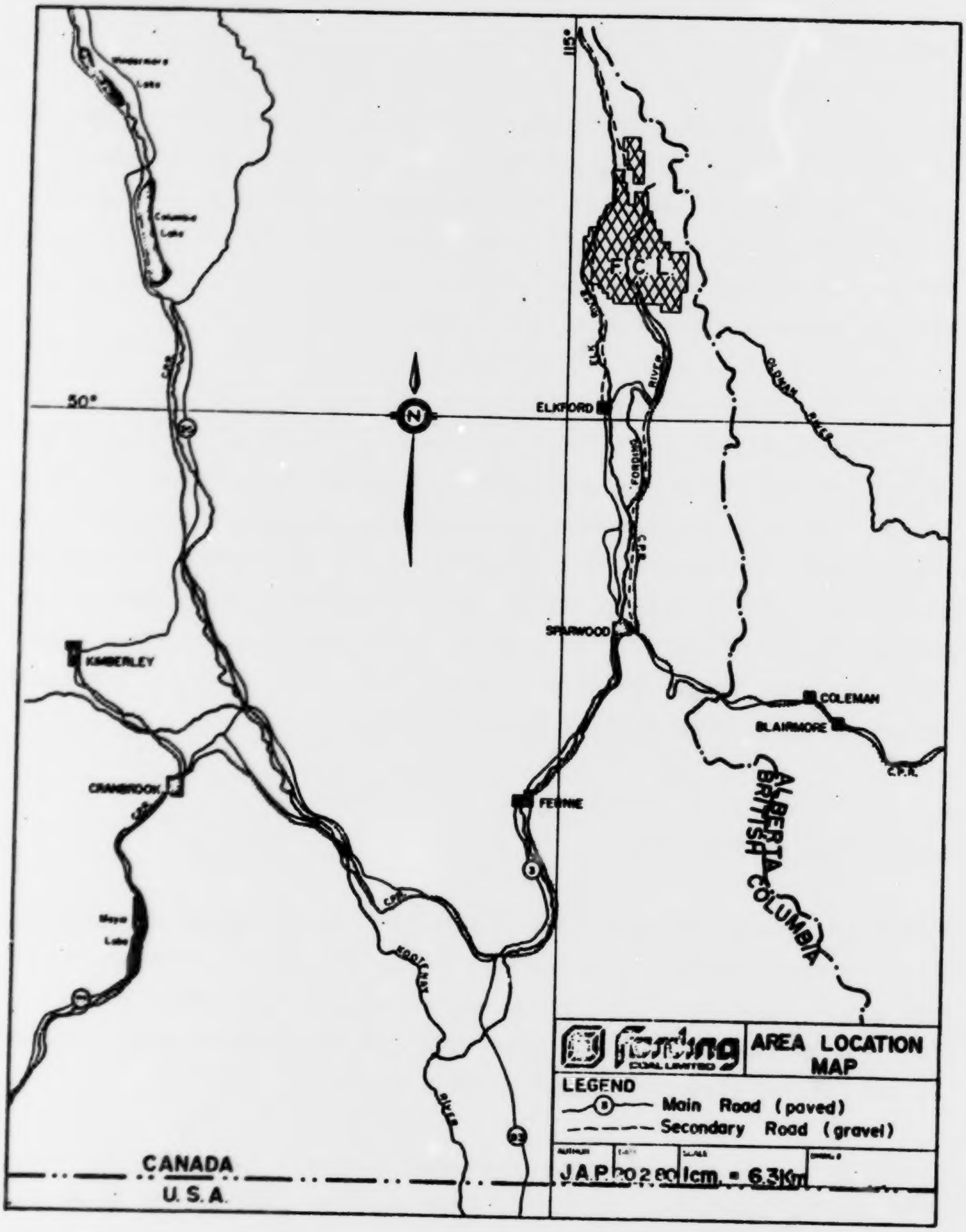


Table 1

FORDING RIVER MINESITE - AVERAGE CLIMATIC DATA, 1973 TO 1977

Mean Annual Temperature	14°C
Mean Monthly Temperature	
January	-8.0°C
July	13.4°C
Months Above 10°C*	3
Months Below 0°C*	6
Months Above 4°C*	5
Frost Free Days	30 to 40
Annual Precipitation	737 mm
Annual Snowfall	386 cm
Wettest Season	Winter
Driest Season	Summer

*Based on 1973, 1974 and 1975 data.

mainly forest, in which the dominant coniferous species are Englemann spruce, lodgepole pine, and minor amounts of subalpine fir and Douglas fir.

Occasionally stands of alpine larch occur on north slopes at elevations of 1800 metres or greater, and stands of whitebark pine mixed with grass-shrub communities occur on south and west aspects.

The Canada Land Inventory has classified the Upper Fording River area into its major resource capabilities. The river valley and lower mountain slopes have been classed as moderate big game range and moderate yield forest. As moderate big game range, this area has some limitations for the production of ungulates, but is important for year round or seasonal use. Moderate yield forest has a productivity that ranges from 3.6 m^3/ha/yr to 4.9 m^3/ha/yr, making it desirable for harvesting, especially in valley bottoms. This area is also valuable for recreation pursuits such as hunting, fishing and hiking.

The mid-slope to mountain peak area has been classed as moderate big game range, prime big game range, limited yield forest and highland. The prime big game range occurs on the southerly slopes of Eagle, Castle and Turnbull mountains. The limited yield forest has a productivity ranging from 2.2 to 3.5 m^3/ha/yr, making it undesirable for harvesting. The highland class is high elevation land with capabilities for both big game range and extensive recreation such as hiking and riding, mountain climbing, wildlife viewing and hunting.

GEOLOGY AND MINE LAYOUT

Metallurgical and thermal coal seams occur in the lower 600 metres of the 1300 metre Kootenay formation on both sides of the Fording River valley. Figures 2 and 3 show the existing mine layout and geological sections, respectively. The major structural features are two subparallel synclines; one on each side of the valley running north-south, and a regional fault along the west side of the Fording River.

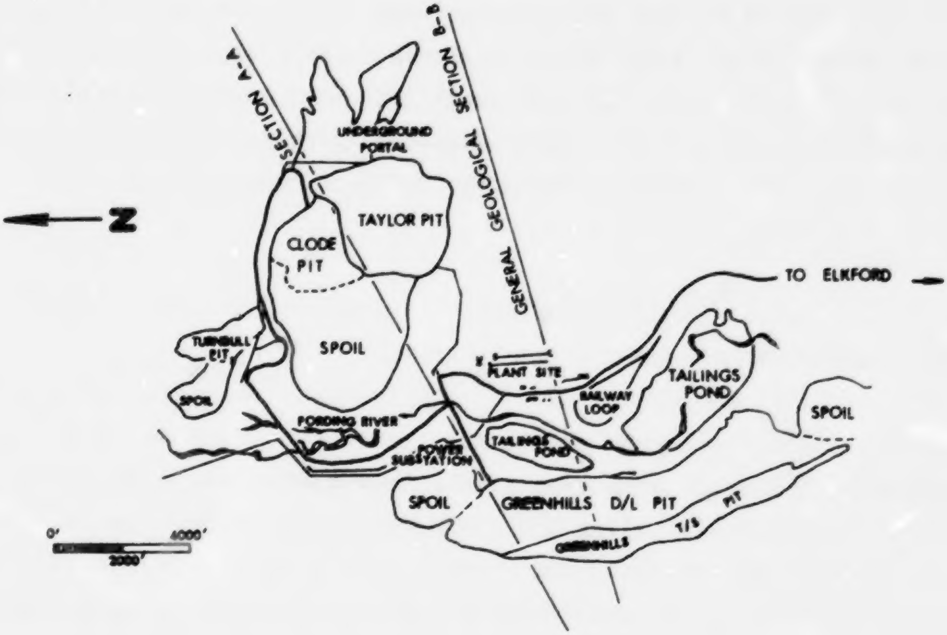


FIGURE 2 FORDING RIVER OPERATIONS SURFACE PLAN

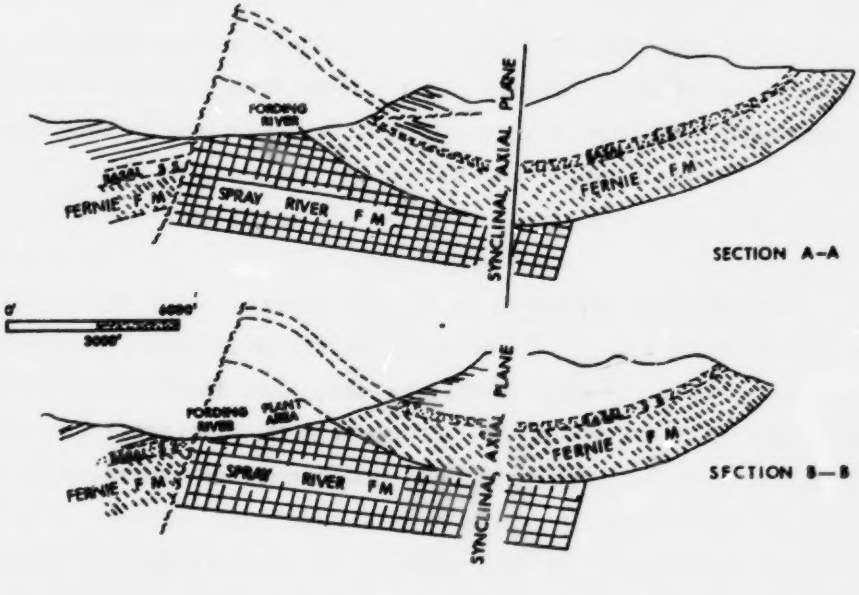


FIGURE 3 GENERAL GEOLOGICAL COAL SECTION

Truck-shovel operations exist on the eastern side of the valley. Dragline mining with truck-shovel prestrip exists on the western side. Both operations create massive quantities of waste which will require extensive site preparation for reclamation purposes. Mining operations also intercept numerous secondary drainage patterns leading to the Fording River.

WASTE DUMP DESIGN - GENERAL CONSIDERATIONS

Multi-seam coal mining in mountainous terrain creates more waste volume per unit of surface area than single seam operations. The narrow and steep Fording River valley and the lateral and vertical extent of the coal formations in the area, both create problems in fitting large spoil volumes into the available non-resource areas. These two factors make spoil dump designs one of the more critical components of mine planning.

The major factors that must be considered in waste dump design are: location and extent of coal reserves in the dump area, volume of spoil to be accommodated, haulage distances, stability of spoil, hydrology and drainage of the dump area, proximity to the Fording River flood plain, and the resloping requirements to permit adequate reclamation.

All economic open pit coal reserves must be recovered prior to coverage by waste material, and spoil volume must be maximized because of the limited surface area available for waste dumps at the Fording River operations. Haul distances must be optimized with consideration being given to both the vertical and horizontal components of the route.

Stability of the spoil must be assured by giving consideration to both the surface materials on the natural topography and the spoil material itself. The spoil area hydrology must be investigated to ensure that spoil stability is not adversely affected by subsurface or surface drainage. Drainage systems must be established above, below and through the spoil to ensure that water quality can be maintained at an acceptable level. All waste dumps at the minesite are planned above the 1,000-year flood level and away from the "meander belt" of the Fording River. And, finally, adequate room must be left at the base of the spoil to ensure that it can be resloped to 26°.

CASE STUDY - "C" SPOIL EXPANSION IN THE SOUTH GREENHILLS

Fording Coal proposes to extend the "C" spoil waste dump located at the southern end of the Greenhills mining zone (Figure 4). This waste dump is being expanded to accommodate future spoiling from the Greenhills Truck/Shovel 1 and 2 pits.

The proposed spoil area is located on the west side of the Fording River valley on a moderate to gently sloping east facing slope. Most of the area has been disturbed by logging activities in the past. The remaining forested section consists of over-mature Englemann spruce mixed with subalpine fir and lodgepole pine. Swift Creek, a major drainage basin, will be affected by the spoil as well as a number of ephemeral streams on the east facing slope (Figure 5).

GREENHILLS SPOILING - GENERAL INFORMATION

The truck/shovel dumps in the Greenhills area have been developed on gently sloping ground above the west side of the Fording River. The maximum slope on the natural ground surface within the spoil foundation area is approximately 17°. With the exception of peat-filled areas, the foundation material is glacial till mantled by a thin veneer of topsoil. The till is dense and relatively incompressible and exhibits high shear strength making it capable of providing adequate foundation support for waste dumps. Peat and organic soil deposits occur in isolated depressions in the upper surface of the glacial till. Thickness of these deposits can extend to a depth of 6 metres.

Figure 4

"C" SPOIL WASTE DUMP - GREENHILLS MINING ZONE

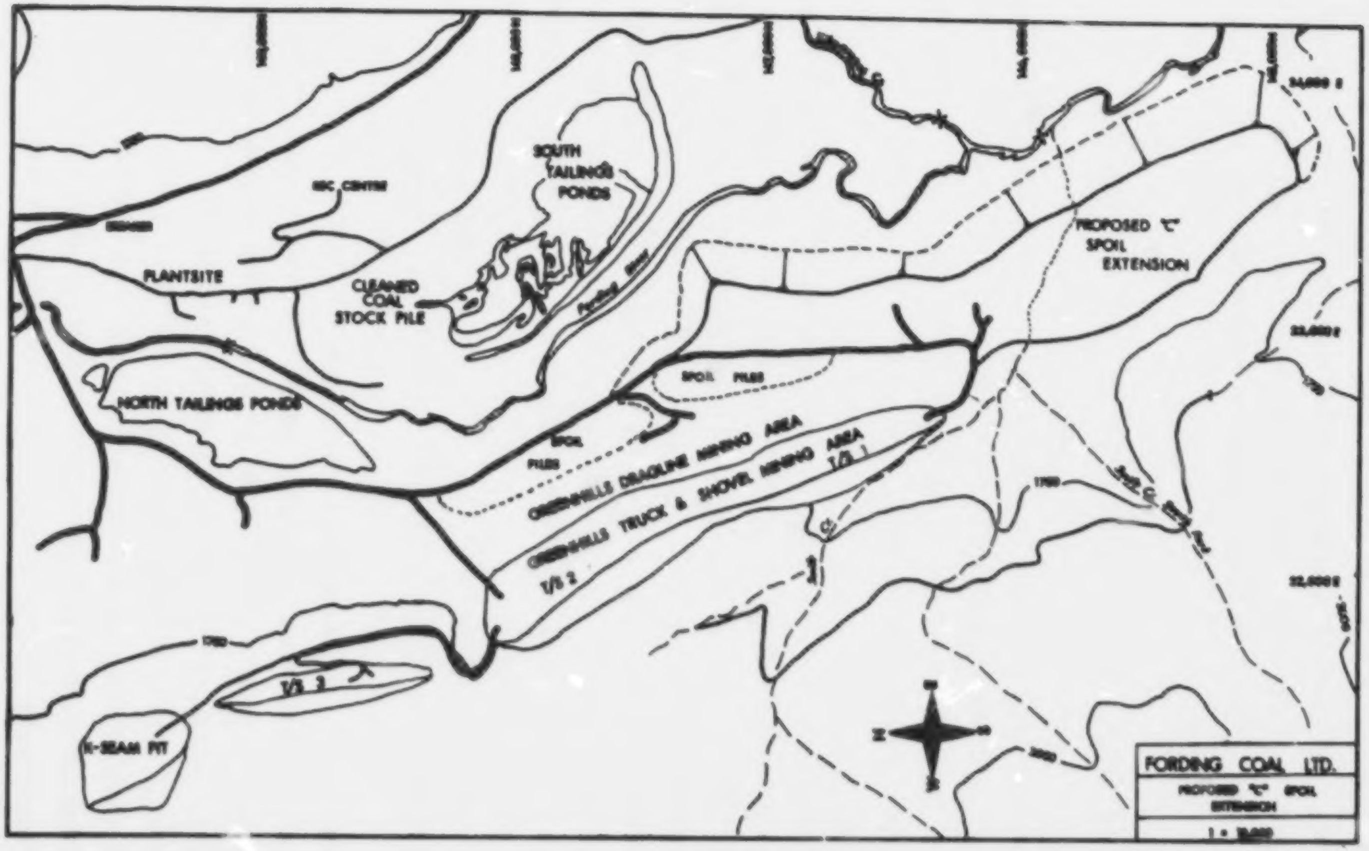
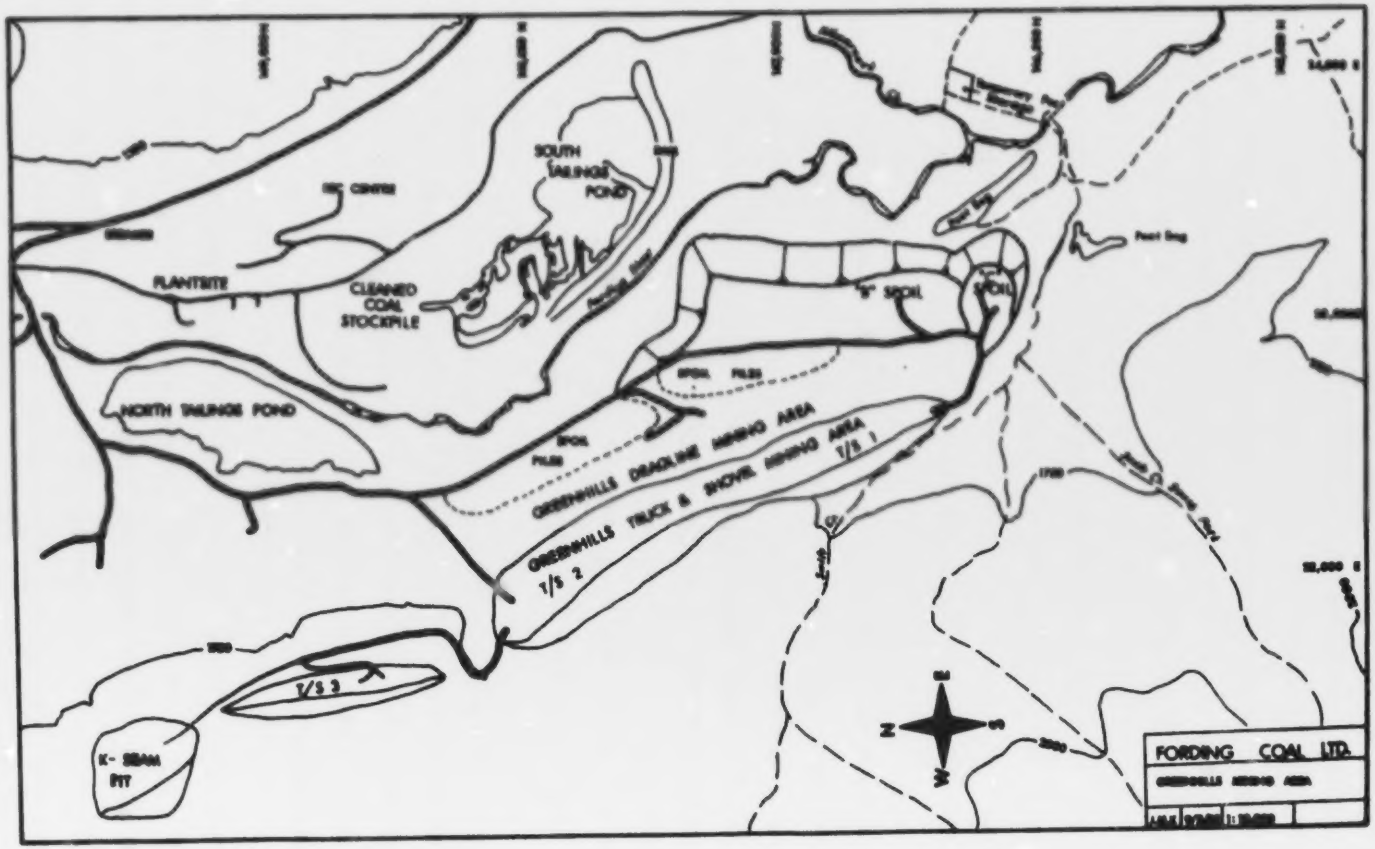


Figure 5

LOCATION OF SWIFT CREEK IN THE GREENHILLS MINING ZONE



Stability of the Greenhills waste dumps is governed by the shearing resistance of the near surface foundation soils on which the dump is constructed, the shear strength of the materials comprising the dump itself, and by water pressures within the spoil pile. Observations at older spoil areas along the Greenhills dragline waste piles show that when the toe of a waste dump advances onto peat deposits, the organic soils undergo large horizontal displacements resulting in failure and slumping at the toe. To guard against further failures, the organic deposits have been encircled by the dump or have been removed. This prevents the organic deposit from spreading beyond its boundaries, because the waste rock zone around its perimeter serves as a confining dyke for the material placed over it.

Disposal of waste material over the advancing face of the waste pile will produce segregation of the waste rock. The largest and most durable fragments of waste rock come to rest at the base of the spoil. This coarse rock zone at the base of the spoil will preclude the development of pore pressures within the spoil pile.

"C" SPOIL WASTE DUMP DESIGN

The proposed waste dump extension will cover an area of approximately 80 hectares and accommodate a spoil volume of approximately 40,500,000 cubic metres. No mineable coal reserves occur in the spoil area as it lies stratigraphically below the basal sandstone of the coal bearing sequence.

The remaining forest cover and any surficial materials which affect the stability of the dump will be removed from the spoil area prior to construction. Two deposits containing peat have been identified and are presently being removed (Figure 5). The largest of these peat deposits is located near the outside edge of the spoil in the vicinity of the Fording River where the occurrence of a spoil failure could have severe effects on the river. This deposit contained 90000 LCY of peat. The other, much smaller deposit, is located adjacent to Swift Creek where a spoil failure could have long-term effects on the water quality of the stream.

In the initial development of the spoil, a ramp will be constructed across the Swift Creek drainage basin to access the spoil area south of the creek (Figure 6). In the final stages of development, the spoil will completely cover the lower portion of the Swift Creek channel immediately above its outlet to the Fording River.

DRAINAGE

There are three alternatives being considered to deal with the Swift Creek drainage. The first, is to divert the entire flow of Swift Creek around the spoil area and discharge it into the next drainage system to the south. Diversion ditches have been used extensively at the Fording River minesite, and experience has shown that these structures are costly to construct and maintain. Diversion ditches represent only a short-term solution to the drainage problem due to the regular maintenance requirement and because, historically, they have been a problem with regard to water quality.

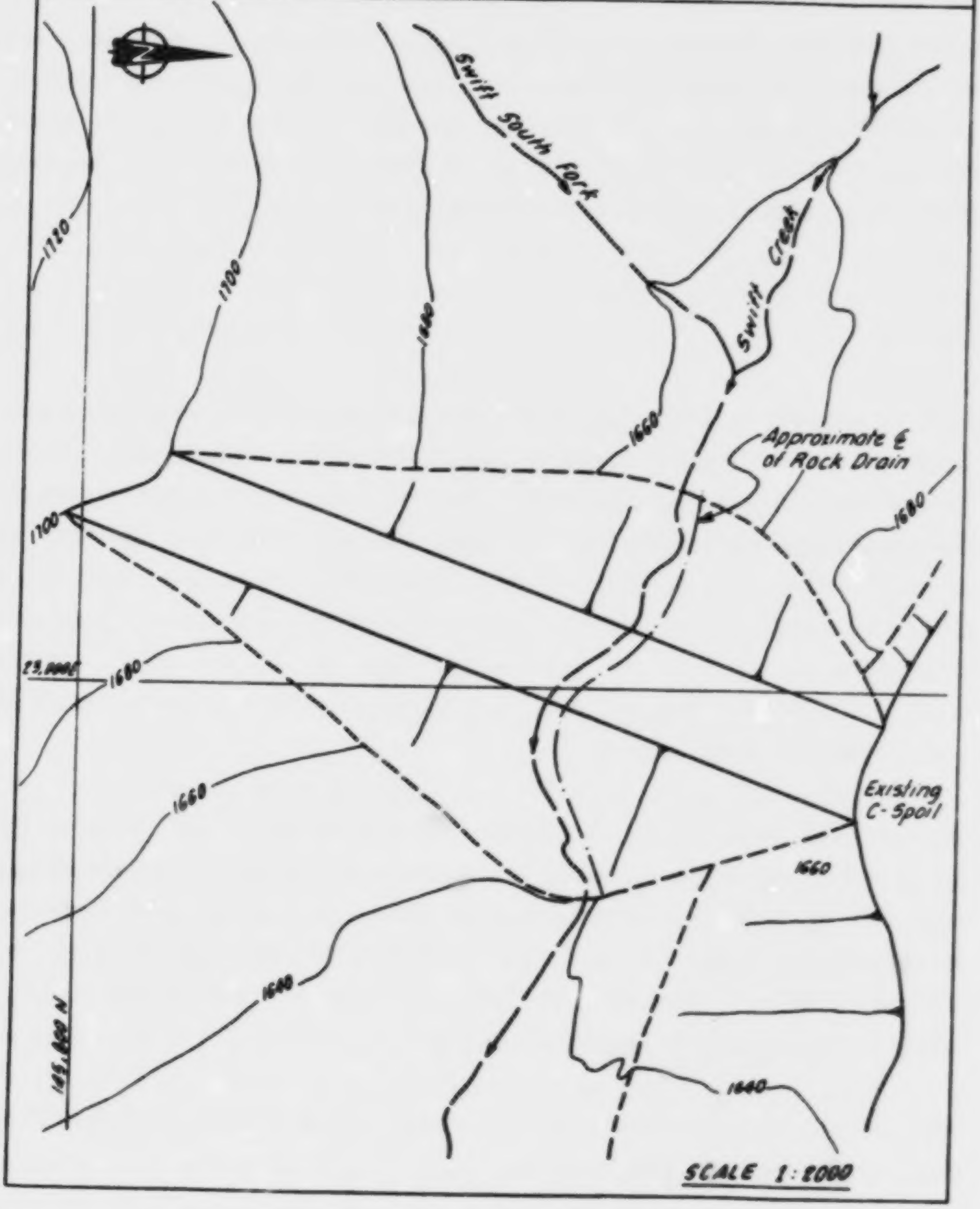
The second alternative is to construct a coarse rock drain through the spoil along the original Swift Creek drainage course. The advantages of a rock drain over a diversion ditch are that the drain is virtually maintenance free and it represents a final long-term solution to the drainage problem. However, the effectiveness of rock drains through spoil dumps has yet to be tested in B.C.

The third alternative is to place a large culvert through the spoil to allow Swift Creek to flow through.

To determine the best alternative, a study is being undertaken to assess the hydrology and stability of a rock drain through the proposed

PLAN SHOWING PROPOSED
SWIFT CREEK CROSSOVER

Figure 6



ramp over the Swift Creek channel. A preliminary design for the rock drain structure is shown in Figure 7. The rock drain will be constructed using sandstone rocks of the 0.6 to 1.0 metre size. The topsoil will be stripped from the area covered by the rock drain. A base pad of 8 inches (0.2 metre) thickness minus rock material will be constructed under the rock drain to prevent scouring of the natural ground below the drain structure. When the rock drain structure has been constructed, the spoil will be advanced southward to form the cross-over ramp.

The rock drain and existing creek channel will be situated parallel to each other along the bottom of the creek basin, to test whether or not an adequate rock drain is produced by end dumping material from the crest of an advancing spoil. If the hydraulic conductivity of the normal spoil base is insufficient to handle the water flow, the excess flow will go through the rock drain. Monitoring stations will be set up at both ends of both the rock drain and the natural water channel to determine the water flows through each structure.

Culverting has been dismissed as a solution to drainage through the spoil due to maintenance problems, the high risk of structural failure, and the preparation requirements in the drainage location.

Considerable time and money will be saved if it can be demonstrated that rock drains are effective in channeling drainage through a waste dump. Further studies are needed to examine alternative methods of constructing rock drains. Such studies would be particularly applicable for the Swift Creek drainage where it will be possible to simultaneously spoil-over the creek channel from both sides. This will result in not only a rock drain over the original channel but also a coarse rock core up through the spoil itself (Figure 8), thereby further reducing a possible blockage of water flow which could impair waste dump stability.

FIGURE 7

PRELIMINARY DESIGN FOR THE ROCK DRAIN STRUCTURE

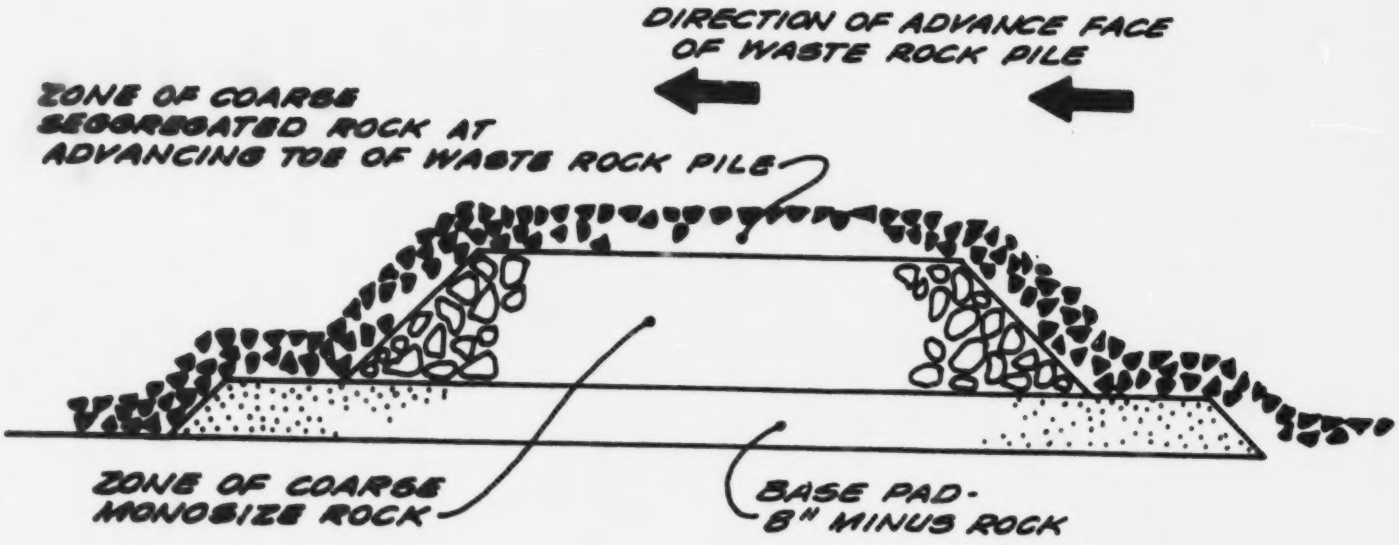
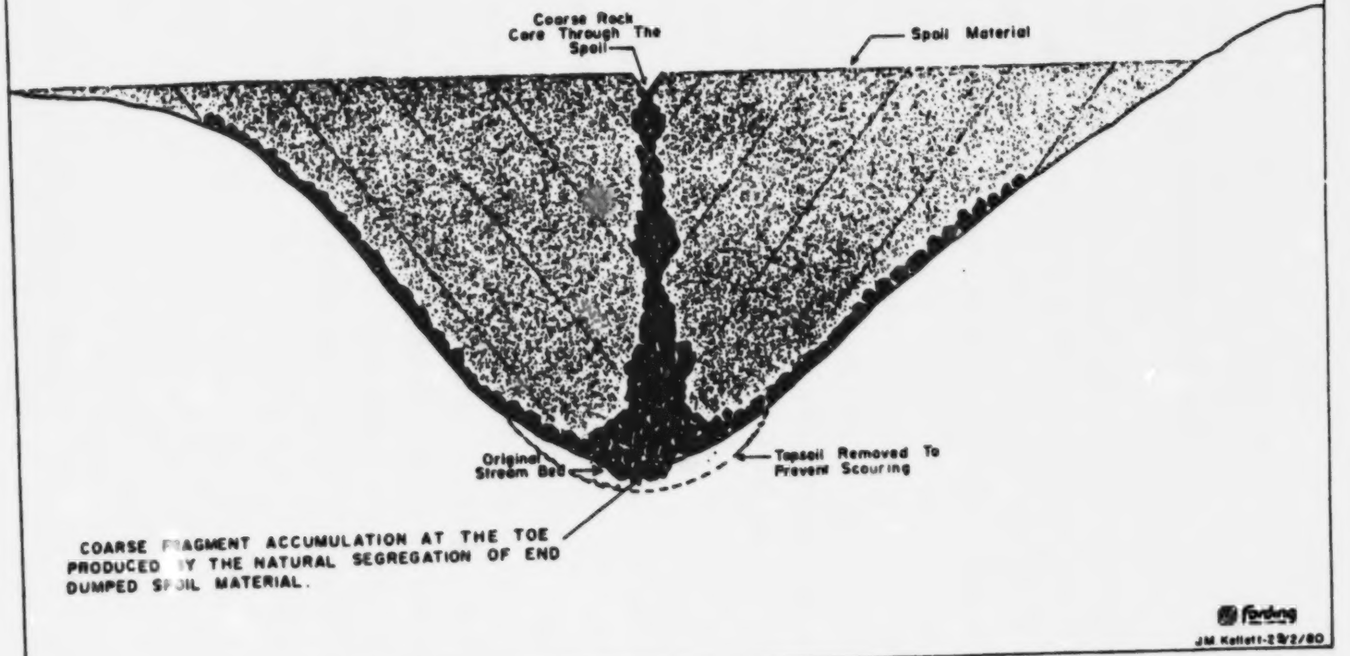


FIGURE 8

A COARSE ROCK DRAIN PRODUCED BY SIMULTANEOUS END DUMPING FROM TWO DIRECTIONS


Coarse Rock Core Through The Spoil
Spoil Material
Original Stream Bed
Topsoil Removed To Prevent Scouring
COARSE FRAGMENT ACCUMULATION AT THE TOE PRODUCED BY THE NATURAL SEGREGATION OF END DUMPED SPOIL MATERIAL.
Fording
JM Kellett-29/2/80

Drainage through rock drains in the spoil is expected to yield better water quality than that presently obtained in the existing diversion ditches.

RECLAMATION OF PROPOSED SPOIL EXTENSION

The Canada Land Inventory System has classed the proposed spoil area as moderate yield forest. The area is not an important wildlife habitat as it is used only occasionally by elk, moose and black bear. Area activities have been limited to logging and some exploration.

The reclaimed toe of the proposed spoil will be well above the 1,000-year flood level of the Fording River. A buffer zone of adequate width will be left between the toe of the spoil and the Fording River so that any runoff generated from the spoil face will not contaminate the river.

The reclamation objective for this waste dump will be to re-establish moderate yield forest, although southfacing slopes will be reclaimed to provide additional summer and winter range for ungulates. The spoil face will be resloped to 26° and seeded with agronomic grasses and legumes for initial stabilization of the surface material. After initial stabilization, native species of coniferous and deciduous trees and shrubs will be introduced. These native species will be propagated in greenhouse and nursery facilities from locally collected materials.

COMBINED DISCUSSION RELATED TO R. BERDUSCO, C. PELLETIER AND D. LANE'S PAPERS

Paul Christie - Talisman Land Resource Consultants: I'd like to ask Mr. Lane what you're doing with peat material?

D. Lane - Answer: In our present program for removing peat material, we have tried, where possible, to separate the surface foot and the bottom foot of the peat. The surface material tends to get soil and live vegetable matter mixed in with it. It has been stored on one stockpile, and the good peat of commercial value has been separately stockpiled. Some of the peat may be kept for reclamation purposes, but I think that if we can sell it, we will. Peat is not a good surface dressing because it tends to blow away when it gets dry. It's a rather expensive process to mix peat with till, sand, or some other medium. At the present time we try to salvage the good material.

Questioner Unidentified: I'd like to ask about moving that material at (?) Mile Creek. Do you have any ballpark cost figure?

R. Berdusco - Answer: The question perhaps relates to the cost of moving four hundred thousand yards last summer and, unfortunately I don't have a specific cost. We used three D9 dozers for the better part of four and one half months to move the equivalent of ten thousand gross TOH. At current operating costs, that's around one million dollars.

Mel Cochrane - Ministry of Lands, Parks and Housing: I have a question for Mr. Pelletier. Can you give an idea of what might be done with the pit at Island Copper. Can you expand briefly on your beach improvement studies?

C. Pelletier - Answer: An answer to your first question, we've had discussions with various government departments, and I think the tentative plan is to open up a channel and grade a deep submarine basin, which would be the pit. For your second question on the dump area, the major impact on Grouper Inlet has to be the taking of the shoreline out of biological production. If we leave the dump the way it is, it's unstable because there's a fourteen-foot tide plus wind action hitting against it as well as continued slumping and undercutting. You need a relatively stable environment for the flora and fauna to grow on. That's why we developed our research plot, which is about 200 to 250 feet wide. We're working from the south tidal area to the top of the high tide mark by setting up a grid system and monitoring the floral and faunal colonization of the area. Successional development of the fauna is also being watched, to find out which group starts first and how it develops. It's basically an opportunistic research project because that part of the dump is going to be buried in a year or two.

IRRIGATION

Chairman of the Afternoon Session

Thursday, March 6, 1980

B. Switzer

Denison Coal Ltd.

IRRIGATION EQUIPMENT AND DESIGN OF IRRIGATION SYSTEMS

by

Ted Van der Gulik

Ministry of Agriculture

IRRIGATION EQUIPMENT AND DESIGN OF IRRIGATION SYSTEMS

INTRODUCTION

The purpose of this presentation is to present the advantages and disadvantages of different types of irrigation systems currently available to farmers. The main types of irrigation systems used on pasture, corn or alfalfa crops are handmove, wheelmove, guns on tripods, travelling guns and pivots.

HAND AND WHEELMOVE SYSTEMS

The relatively inexpensive handmove systems are still being used throughout B.C., but are slowly being phased-out by less labour intensive methods.

Wheelmove systems are a good alternative to handmove on larger rectangular shaped fields, and are popular because of the simple operation involved in moving the lateral from one location to another. A false belief is that these systems are capable of independent movement while irrigating; but this is impossible. The pipe would be unable to withstand the torque required to roll the system ahead if it were full of water. The lateral must be completely drained before the system can be advanced. Each section of pipe on the lateral contains a small drain which automatically opens once the water pressure is relieved.

There are wheelmove systems available which will automatically advance themselves two positions when required. They consist of a mover with an electronic timing board, and a 100-foot length of flexible hose complete with an automatic valve attachable to the hydrant. When a watering set has been completed, the timing board automatically shuts off the valve which allows the entire wheel line to drain. After a set period of time, the engine is automatically restarted to advance the system - usually 60 feet. The engine then shuts off and the valve is re-opened to allow the system to continue irrigating.

The advantage of a wheelmove system is that it substantially reduces labour requirements for a relatively small increase in cost. The main disadvantages are that wheelmoves are not effective in irregularly shaped fields or rough terrain, and are incapable of irrigating crops such as corn.

GUN SYSTEMS

A large percentage of British Columbia's corn crop is irrigated with gun systems. The simplest of these is a gun operating on a tripod. Water is distributed to the tripods by a long flexible hose or portable aluminum pipe. The tripod must be moved from one location to another three or four times per day and, although this can be done quickly, it must be done so often on larger acreages that these systems are very labour intensive. Labour requirements can be reduced by installing a network of underground piping with properly spaced hydrants, so that the portable gun can be quick-coupled to any hydrant. This latter system is expensive because of the extensive lengths of piping required. The advantage of a portable gun system is that it distributes water effectively regardless of the shape or terrain of a field.

If the field is larger than 20 acres and a gun system is preferred, a travelling gun is usually the best method to use. These systems are popular because irregular shaped fields can be irrigated with minimal labour.

There are two basic types of travelling guns; the winch type irrigator and the reel irrigator. The winch machine draws itself along on a cable anchored at the end of the field, dragging the supply hose behind it. The reel irrigator reels in the hose and gun while the machine itself remains stationary. The two types of machines differ greatly in operation but are similar in irrigation performance.

To operate a winch type irrigator, the cable must first be drawn out with a tractor and anchored at the end of the field. The hose must also be drawn out and connected to the hydrant as well as to the traveller. When the traveller has completed its run, a purge pump should be used to remove the water from the hose. The hose must then be reeled in on a trailer, moved to a new location, and then drawn out again. The traveller must also be moved to the new location and the cable drawn out.

The reel irrigator requires less labour then the winch irrigator for two reasons; the hose and gun are drawn out together, and the machine reels in the hose as it is operating. When the irrigation cycle has been completed the entire system can be towed to a new location. The hose used on the reel irrigator is a hard durable plastic and is not collapsible as is the hose on the winch irrigator.

Most travelling guns are powered by available water pressure. The two basic types of driving mechanisms available are the piston drive and the turbine drive. A piston drive system is a bit jerky and needs to release some water from the system as it moves. This water must be disposed of near the machine. The turbine drive is quiet, smooth and does not discharge any water; however, it requires slightly more power than the piston drive. The limitations of all travelling guns are their:

a. high water application rates so they do not operate very efficiently on soils with low infiltration rates (i.e. muck or clay)

b. requirement for a much higher connection pressure than other systems because of the friction losses in the hose and power required for the driving mechanism

c. need for special care and attention in operation because of the high pressures and the intricate mechanisms involved.

CENTRE-PIVOT SYSTEMS

Centre-pivot systems are popular in the United States. They are generally permanent installations on very large acreages and are available with either hydraulic or electric drive. Twenty to thirty of these machines are working satisfactorily in British Columbia.

Most British Columbia farms are of small acreage, so pivot manufacturers have developed (but not yet marketed in the province) a small pivot which can be end-towed from field to field. The advantages of the small pivot are that it can:

a. irrigate odd-shaped parcels of land by distributing water in partial circles;

b. be set up and then operated with minimal labour;

c. apply the exact quantity of water needed by the crop;

d. operate on much less pressure than travelling guns because low pressure nozzles can be used.

Its principal disadvantage is that it takes three to four hours to move them from one location to another.

IRRIGATION SYSTEM DESIGN

For proper irrigation system design, information regarding crops, soils and climate must be acquired. It is also necessary to know the type of crop, soil depth and soil texture (see Figure 1). The evapotranspiration rate is also important, consequently, to assess this, wind speeds and precipitation data are required.

The system can be designed by completing the 13 planning steps which follow:

Step 1 Determine the effective rooting depth of the crop.

From Table 1 we find that alfalfa, for example, has an effective rooting depth of four feet.

Step 2 Determine the soil texture and the depth of each soil layer.

Step 3 Determine the available water storage capacity.

Once the soil texture is known, the available water storage capacity of that soil can be determined from Table 2. (Sandy loam 1.5 in./ft.)

Step 4 Calculate the total available water storage capacity for the entire rooting depth.

Assuming we have four feet of sandy loam soil, then the total available water storage capacity = 4 x 1.5 = 6.0 inches of water.

Step 5 Determine the maximum allowable soil deficit. Alfalfa can effectively extract only 50% of the total available water storage capacity before it begins to suffer (Table 3). The maximum allowable soil deficit is therefore (6.0 in. x 0.50) = 3.0 inches of water.

Step 6 Determine the maximum design application rate.

Soils have the capability of absorbing water at a certain rate over a specified period. The intake rate decreases as time increases. For most irrigation designs we are interested in a long application period. From Table 4, the maximum application rate is 0.45 in./hr. for a sod cover.

Step 7 Determine the evapotranspiration rate.

From Table 5, for One Hundred Mile House the evapotranspiration is 0.20 in./day.

Step 8 The safe irrigation interval is the maximum soil water deficit over the evapotranspiration rate.

3.0 in./0.20 in./day = 15 days

Step 9 Select an appropriate application efficiency.

A figure of 72% is a good value to use for a sprinkler system.

Step 10 Calculate the depth of water that must be supplied by the irrigation system.

$$\frac{3.0\ \text{inches}}{0.72} = 4.16\ \text{inches}$$

Step 11 Calculate the minimum time of application.

$$\frac{4.16\ \text{inches}}{0.45\ \text{in./hr.}}\ \frac{(\text{Gross water required})}{(\text{Max. appl. rate})} = 9.2\ \text{hours}$$

Step 12 Select an appropriate application time.

e.g. 11-1/2 hours leaving 1/2 hour for moving the system.

The design application rate = $\frac{4.16}{11\text{-}1/2}$ = 0.36 in./hr.

Step 13 Select a sprinkler.

After a spacing is chosen, Table 6 can be used to select a sprinkler.

Application rate = 0.36 in./hr.

Sprinkler nozzle: 3/16" x 3/32"
Pressure: 49 psi
Flow rate: 9.0 gpm
Application efficiency: 72%

The final system design consists of 9.0 gpm sprinklers operating at 49 psi on a 40 x 60 foot spacing. The net amount of water applied to the crop in 11-1/2 hours is 3.0 inches, which will allow for an irrigation interval of 15 days on the sandy loam soil.

Table 1

EFFECTIVE ROOTING DEPTHS OF CROPS

GROUP 1 Shallow Irrigation (1-1/2')	GROUP 2 Medium Irrigation (3')	GROUP 3 Deep Irrigation (3' plus)
Peas	Potatoes	Alfalfa
Beans	Beets	Asparagus
Lettuce	Broccoli	Tree fruits
Onions	Carrots	Hubbard squash
Radish	Strawberry	Corn (field)
Spinach	Cane fruit	Grapes
Celery	Squash	
Cauliflower	Corn (sweet)	
Cabbage	Cereals	
Ladino	Tomatoes	
Turnip	Peppers	
Cucumbers	Eggplant	
Pasture species	Brussels sprouts	
	Red clover	

Table 2

AVAILABLE WATER STORAGE CAPACITY (AWSC)

TEXTURAL CLASS	INCHES OF WATER PER FOOT OF SOIL		
	Field Capacity	Permanent Wilting Point	Available Water Storage Capacity
Sand	1.3	0.3	1.0
Loamy Sand	1.7	0.5	1.2
Sandy Loam	2.2	0.7	1.5
Fine Sandy Loam	2.6	0.9	1.7
Loam	3.3	1.2	2.1
Silt Loam	4.0	1.5	2.5
Clay Loam	4.5	2.1	2.4
Clay	4.6	2.2	2.4
Organic Soils Muck	to be added		3.0

Table 3

AVAILABILITY COEFFICIENT (MAXIMUM FRACTION OF AVAILABLE WATER STORAGE CAPACITY TO BE REMOVED BEFORE IRRIGATION IS REQUIRED)

CROP	AVAILABILITY COEFFICIENT
Potatoes	0.35
Tree Fruits	
(Coarse textured soils)	0.40
(Other soils)	0.50
Peas	0.35
Remainder of Crops (Until additional data available)	0.50

Table 4

MAXIMUM DESIGN APPLICATION RATE

	INCHES PER HOUR	
	Grass Sod	Cultivated
Sand	0.75	0.40
Loamy Sand	0.65	0.35
Sandy Loam	0.45	0.25
Loam, Silt Loam	0.35	0.20
Clay Loam, Silty Clay Loam	0.30	0.15
Clay	0.25	0.10
Peat and Muck	1.0	1.0

FIGURE 1

GUIDE FOR TEXTURAL CLASSIFICATION

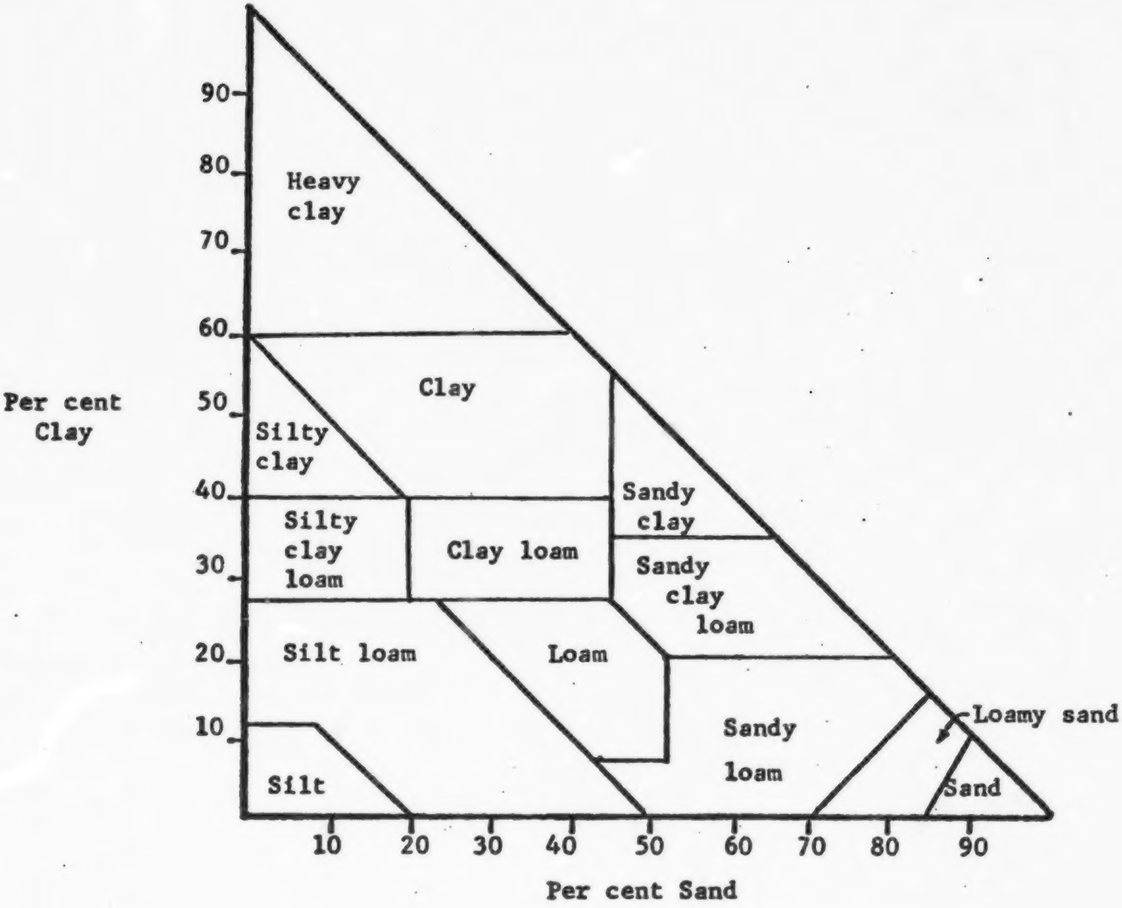


Table 5

DETERMINATION OF MAXIMUM DAILY WATER USE FOR VARIOUS AREAS IN B.C.

LOCATION	MAXIMUM AVERAGE DAILY WATER USE FOR		
	10-day period in inches/day	20-day period in inches/day	30-day period in inches/day
Lumby	0.23	0.22	0.21
Lytton	0.29	0.28	0.27
Malakwa	0.20	0.18	0.18
Merritt	0.26	0.25	0.24
Nanaimo	0.19	0.17	0.16
Natal	0.18	0.17	0.16
Notch Hill	0.20	0.19	0.18
Oliver	0.25	0.23	0.22
One Hundred Mile House	0.20	0.19	0.18
Osoyoos	0.28	0.27	0.26
Oyster River*	0.17	0.15	0.13
Parksville	0.17	0.15	0.14
Pitt Meadows	0.17	0.15	0.13
Port Alberni	0.20	0.19	0.18
Prince George*	0.22	0.18	0.16
Princeton	0.25	0.24	0.23
Quesnel*	0.23	0.22	0.21
Radium	0.20	0.19	0.18
Riske Creek*	0.24	0.22	0.21
Saanichton*	0.17	0.16	0.15
Salmon Arm	0.17	0.16	0.16
Smithers	0.17	0.15	0.14
Spillimacheen	0.20	0.19	0.19
Sumas	0.17	0.16	0.15
Summerland	0.25	0.24	0.23
Terrace	0.20	0.19	0.18
Vancouver	0.18	0.17	0.16
Vanderhoof	0.20	0.19	0.19
Vavenby	0.20	0.18	0.17
Vernon	0.23	0.22	0.21
Walhachin	0.25	0.24	0.23
Westwold	0.26	0.25	0.24
Williams Lake	0.24	0.22	0.21

*Values adjusted to actual field experience.

Table 6

SPRINKLER SELECTION FOR 40' X 60' SPACING

APPLICATION RATE (in/hr)	SPRINKLER NOZZLE SIZE (in)	PRESSURE AT NOZZLE (psi)	FLOW PER NOZZLE (US gpm)	COEFFICIENT OF UNIFORMITY (%)	WIND RANGE	APPLICATION EFFICIENCY	
						Cool Climate (%)	Hot Climate (%)
0.13	1/8	51	3.25	86	1-3	75	73
0.14	9/64	37	3.50	85	1-2	74	72
0.15	9/64	43	3.75	86	2-5	74	72
0.16	9/64	48	3.95	83	2-7	74	72
0.17	5/32	37	4.30	80	0-1	74	72
0.18	5/32	41	4.50	86	2-7	74	72
0.19	5/32	46	4.76	87	5-7	74	72
0.21	11/64	38	5.23	86	2-5	74	72
0.22	11/64	42	5.51	86	4-6	74	72
0.23	11/64	45	5.70	86	3-4	75	73
0.24	5/32x3/32	38	6.01	82	3-6	74	72
0.25	5/32x3/32	42	6.25	77	5-10	74	72
0.26	5/32x3/32	45	6.48	79	5-7	74	72
0.27	5/32x3/32	48-1/2	6.73	82	2-6	74	72
0.28	11/64x3/32	40	7.03	82	3-4	74	72
0.29	11/64x3/32	42-1/2	7.25	83	2-3	74	72
0.30	11/64x3/32	45	7.46	85	4-7	74	72
0.31	11/64x3/32	74-1/2	7.70	84	3-6	77	75
0.32	3/16x3/32	40	8.00	84	3-6	78	76
0.34	3/16x3/32	44	8.50	83	3-7	74	72
0.36	3/16x3/32	49	9.00	84	0-1	74	72
0.38	3/16x1/8	40	9.48	84	1-2	74	72
0.40	3/16x1/8	44	10.00	88	3-7	80	78
0.42	3/16x1/8	49	10.50	90	0-1	80	78
0.46	13/64x1/8	46	11.50	85	4-7	78	76
0.48	13/64x1/8	50-1/2	12.00	89	4-8	80	78

DISCUSSION RELATED TO TED VAN DER GULIK'S PAPER

Questioner Unidentified: On how steep a slope would you consider gun irrigation?

Answer: We don't really have any figures on that, but it would be determined by your application rate. You should check the application rate of the kind of gun you have. At the Ministry of Agriculture, we have a manual called the B.C. Irrigation Guide which contains a slope correction factor. If you have, say, a sandy loam soil, and an application rate of 0.45 inches per hour, and you're on a slope, you should decrease the rate by maybe twenty-five percent so you're allowing only 0.3 inches per hour. Then find out what your gun can do, and if it's putting out more than 0.3 inches per hour, you shouldn't be using it. There are many different kinds of guns, and their size will make a big difference to the application rate. The kind of vegetation cover you have is also an important consideration.

Questioner Unidentified: Well, assuming a sandy loam, what would be the maximum slope?

Answer: You should use a small gun on a slope of not more than ten or fifteen percent. It depends upon the type of gun; for example, if you have a gun on a tripod, and your slope is twenty-five degrees, you may have difficulty in keeping the tripod upright.

Questioner Unidentified: Do you have any costs, say, on a per acre basis and on equipment that can be rented?

Answer: When I was in Calgary we rented a system for 80% of the cost of the system. We had to consider possible damage to the rented system. If the guy laid it out in the field and then ran tractors over it, it would come back all bent and beyond further use. So, people will rent, but I'll be very surprised if they'll rent to you at a reasonable rate. The only reason the guy wanted to rent from us was because he needed just a little bit of water for a week. We charged him 80% on the understanding that if it came back in good shape, he would get a rebate of some sort. Renting is not really the best approach, for if you find someone who will rent equipment, you're pretty lucky. The per-acre cost depends a lot upon the size of your acreage. If you have a wheel system and you're irrigating 40 acres, I would say the cost could be about 300 or 400 dollars an acre. If you have a travelling gun system, it would probably be about 500, 600, or 700 dollars an acre. If you're looking at a solid set for orchards, then it would be roughly 1,000 dollars per acre. These costs are only rough estimates. Obviously, a guy can buy a travelling gun and have only twenty acres to irrigate, while the machine is capable of doing forty acres, so his acreage costs are doubled. Costs per acre also depend upon where you are getting the water from, for it may be necessary to pump it a long distance.

WORKSHOP SESSION

WORKSHOP SESSION

VERBAL INTRODUCTION

Thank you Mr. Chairman, ladies and gentlemen. I would like to inform you that the doors of this meeting room have been fitted with automatic sliding bolts keyed to the sound of my voice and the word "workshop". If you haven't escaped by now, you're doomed.

By way of a small apology for what I'm going to inflict on you this afternoon, I'd like to explain how I've come to be here. About four weeks ago Murray Galbraith phoned me and asked if I would chair one of the workshop groups. Thinking he meant one of the tables I said sure. "Good," said Murray, "we'll send you some material we've got together; maybe you have some comments". A week or so later, I phoned Murray back and said that I'd looked over the material and had some comments. "Oh!", he said, "Talk to Errington, he's taking care of the workshop." When I phoned John, his reply was (quote) "What the hell are you bothering me about the workshop for, Murray told me that you were going to run it. Workshops are either good or really rotten and we're getting tired of criticism. Anyway, nobody ever comes to workshop sessions."

There are two morals to this story; first, never trust Murray Galbraith, and second, if you hate the workshop, don't come looking for me, throw Galbraith and Errington in the pool.

As some of you know, I am Secretary of the Coal Guidelines Steering Committee for the Southeast Coal Block. The Coal Guidelines Process has now been in operation for approximately four years. Two of the most important objectives of the process are:

1. To identify the nature and assess the magnitude of the environmental and social impacts associated with proposed coal developments.

2. To coordinate the development of programmes for impact management.

To those of us working in the Guidelines Process, it has become increasingly apparent, particularly as more projects have reached the later stages of the process, that really effective impact management programmes will be developed only through the cooperative planning of government and industry. The guidelines process addresses the question of impacts only on each project in isolation, and yet the impact of a number of projects on a region are going to be at least additive. Some form of regional planning is going to be required if the government resource managers are to meet their objectives, and if industry's environmental management dollars are to be spent in the most cost-effective way. Perhaps one of the major barriers to this type of planning is the lack of a common basis of understanding between government and industry staff: understanding of one another's aims and responsibilities, and the constraints and pressures associated with their respective jobs. As Canada has its "two solitudes", so does resource management in this province. On one side, the mining or geological engineer, working to, what mere mortals might consider, near-impossible deadlines or production schedules, who can't understand why these damned environmentalists keep getting underfoot. At the other end of the spectrum is the government wildlife biologist who must try to manage and preserve a public resource in the face of a diminishing land base, increased public demand for wildlife-based recreation, and a management budget that in terms of real purchasing power has probably declined by about one-third over the last five years.

One of the main values of Symposia such as this is the opportunity to bridge the gulf between people in industry and government. I hope that this afternoon's workshop will go a little way toward achieving that goal. I would like to thank Lynn Bailey, who works with me at the Secretariat, and Carol Jones and Liz Zweck, U.B.C. students, for helping to get the workshop together.

You have been divided up into groups in which we have tried to strike a balance among engineers, reclamationists, environmental control personnel, and resource managers. You have been given a package of information that outlines a proposed coal project and gives some background environmental information on the project area. For simplicity's sake, I have concentrated on information relating to the protection of water quality, wildlife and fisheries. Your task, as an ad hoc industry/government planning team, is:

1. Develop options for mining, waste disposal, haul road location, the location of processing and rail facilities, and exploration.

2. Identify major potential environmental impacts (direct and indirect, on-site and off-site), associated with the development options.

3. Pick a favoured development and explain the economic and environmental criteria that led to your choice.

4. Propose a joint government/industry programme for impact management.

Select a study manager and decide who is going to do various tasks. Each group will be given various implements (coloured pencils, rulers, etc.), a case of beer, and a student to act as participant/recorder. In about two hours, five selected groups will be asked to summarize their work in 3 to 5 minute presentations. After that the session will be thrown open to any other groups with different proposals or perspectives on the problem. Finally, Murray Galbraith will provide a short summary of the workshop. I would caution you that any table that wipes out a fish or wildlife population will have their surface work permit revoked and will be denied bar privileges for the remainder of the Symposium.

At this point, I was going to throw you to the wolves and tell you to get on with the job. But, have you ever noticed that resource inventory maps are completely unintelligible except to the person who prepared them? Well, mine are no exception, so it has been suggested that I quickly go through the resource package to prevent wheel-spinning and ensure that we all have a common point of departure.

1. The Project (transparency)

2. Biophysical Information
    a. Present Status of Coalfield
    b. Surficial Geology (transparency)
    c. Climatic Information
    d. Vegetation (transparency)
    e. Wildlife
    f. Fisheries

Finally, to put all this technical information in perspective, I'd like to tell you the story of an English lady in the old British India who wanted some carpentry work done. She prepared a diagram and hired an Indian carpenter. Unfortunately the man followed the diagram too literally and botched the job. She berated him for not using common sense, whereupon the little man drew himself up with great dignity and said "Memsahib, common sense is a gift of God. I have technical knowledge only." In other words, a little insight is worth a lot of data.

Workshop lists are posted at two locations in the meeting room. If you're not on the list, choose a table for yourself. See you in two hours.

ECOALOGICAL MINING CO. LTD., SHEEP RIDGE COAL PROJECT

PROJECT DESCRIPTION

1. Production level

   2,000,000 tonnes/year of clean metallurgical coal

2. Project life

   20 years (Phase 1)

3. Mine method

   - conventional shovel-truck
   - multibench open pit

4. Details of coal deposit

   - 3 mineable seams contained in a synclinal fold. Seam thickness varying from 3-12 metres
   - Ultimate pit quantities
     - waste 240,000,000 bank cubic metres
     - raw coal 70,500,000 tonnes
     - overall overburden to coal ratio = 3.5 m^3 of waste per tonne of raw coal

5. Preparation plant

   - capacity = 390 tonnes/hour
   - average yield of clean coal = 57%

6. Transportation of clean coal via rail to seaport.

7. Manpower levels

   - 110 staff; 340 hourly

   N.B.: It is estimated that the mine and associated service sector expansion will increase the population of Coalville and vicinity by approximately 2,200 people.

8. An exploration programme is to be undertaken to test suspected coal measures in the vicinity of Goat Range on the north side of Rainbow Creek.

THE TASK

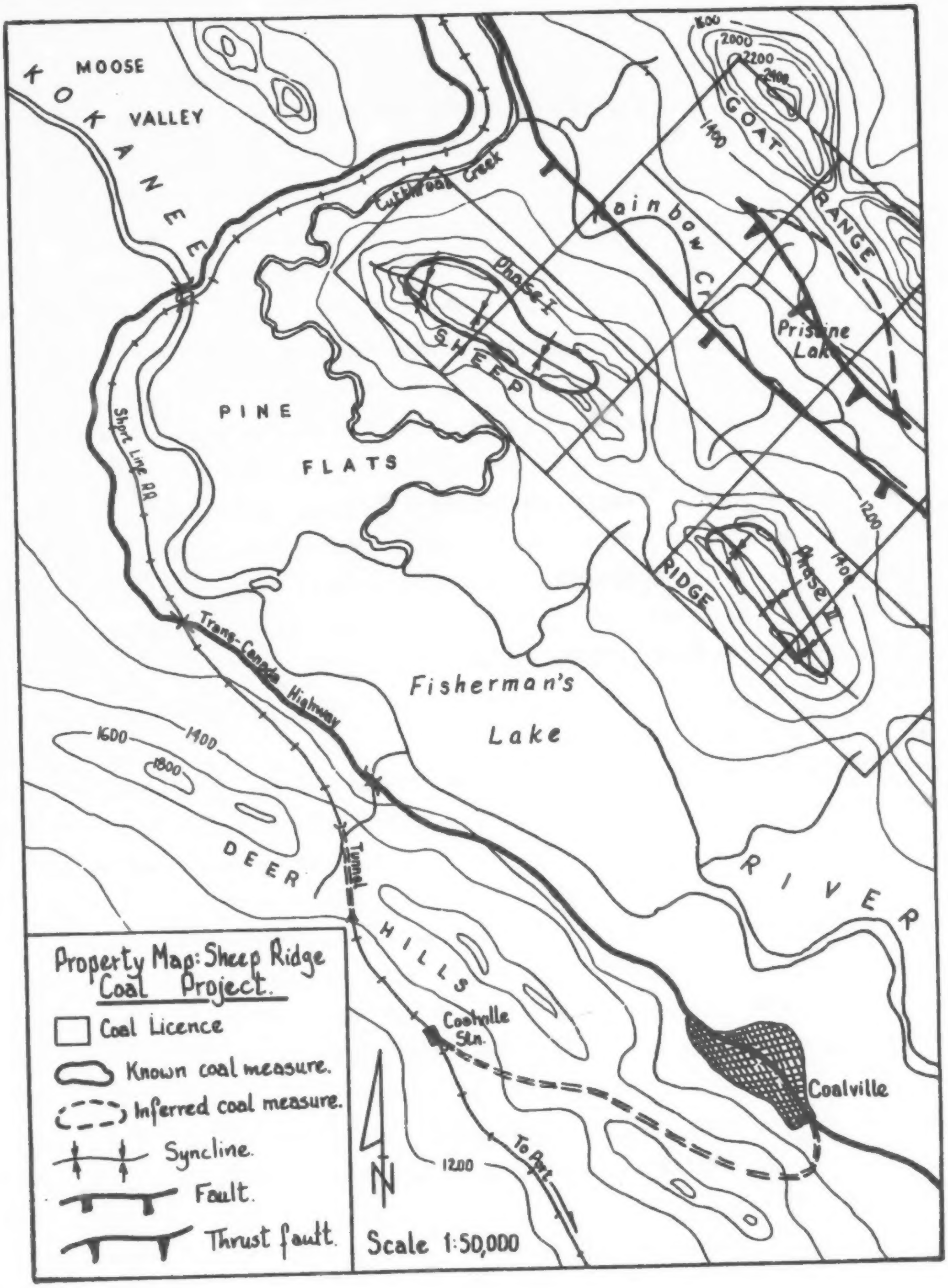
You are an *ad hoc* working group of company and government personnel. On the basis of the attached biophysical information, develop the following:

1. Options for mining, waste disposal, haul road location, the location of processing and rail loading facilities, and exploration.

2. Identify major potential environmental impacts (both direct and indirect) associated with the development options.

3. Pick a favoured development and explain the economic and environmental criteria that led to your choice.

4. Propose a joint government/industry programme for impact management. This programme should deal with both direct and indirect impacts, develop a reclamation programme and place it in an overall impact management context, and identify the types of long term monitoring that would be undertaken to determine the success of the programme.


MOOSE
KOKANEE
VALLEY
Cutthroat Creek
Rainbow Cr.
GOAT RANGE
1600
2000
2200
2400
1400
Phase I
SHEEP
RIDGE
Phase II
Pristine Lake
PINE
FLATS
Short Line RR
Trans-Canada Highway
Fisherman's
Lake
1200
1600
1400
1800
DEER
HILLS
RIVER
Tunnel
Coalville Stn.
Coalville
To Port
1200
Property Map: Sheep Ridge Coal Project.
Coal Licence
Known coal measure.
Inferred coal measure.
Syncline.
Fault.
Thrust fault.
N
Scale 1:50,000

DESCRIPTION OF THE PROJECT AREA

CONTENTS

1. Present Status of the Kokanee Coalfield
2. Surficial Geology
3. Climatic Information
4. Vegetation
5. Wildlife
6. Fisheries

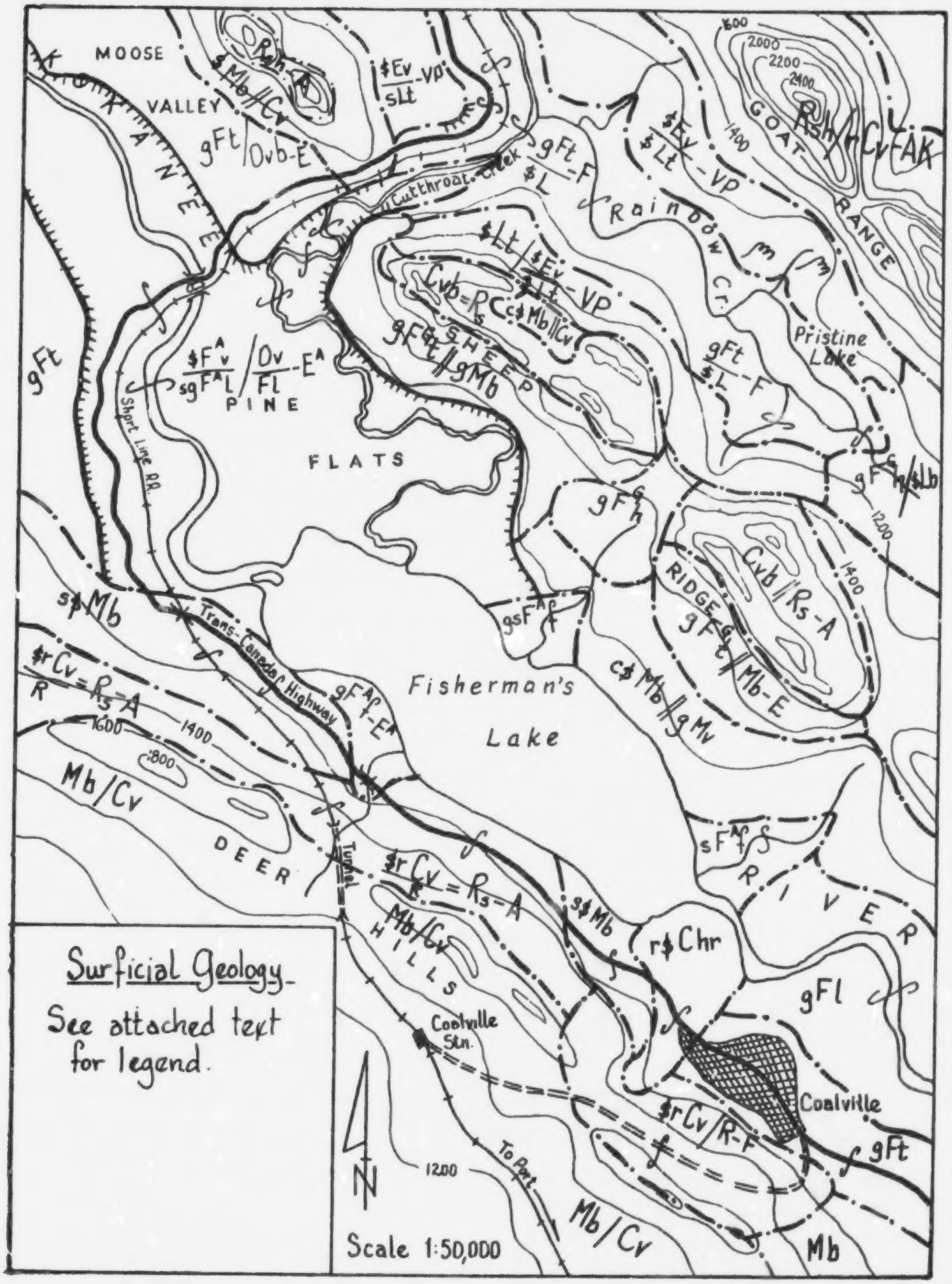
PRESENT STATUS OF THE KOKANEE COALFIELD

The Kokanee Coalfield is located in the southeastern portion of the province between latitudes 49°20'N and 49°30'N. The administrative and residential centre of the coalfield is the town of Coalville, which currently has a population of 2,520. Coalville is located on a secondary artery of the Trans-Canada Highway and is serviced by a branch-line of the Short Line Railroad.

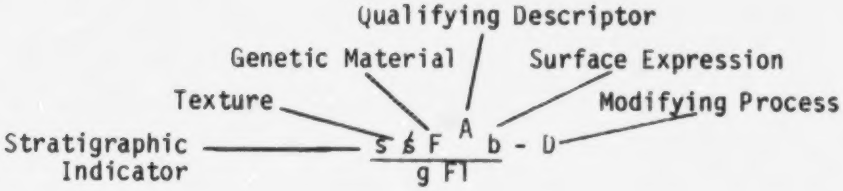
Coal has been mined in the Kokanee Coalfield for the past thirty years. Production, which has fluctuated between 750,000 and 900,000 tonnes per annum, has come from relatively small contour surface mines and underground collieries located east of Coalville. Beagle Brothers Coal Ltd., which has operated here since 1925, is the largest single employer in the area, with a total work force of 330. The forest industry is the next largest employer, and the remainder of the work force is split between the service sector, the Short Line Railroad and a small but thriving tourist industry based on fishing, hunting and the spectacular mountain scenery of the area.

The highway receives only local use during most of the year; however, during the summer considerable numbers of tourists pass through the area on their way to the coast.

The Short Line railway is currently very lightly used. Most of the shipments are either coal from the Beagle Brothers Colliery or grain from the prairies destined for export via the seaport. The roadbed and rails are currently in a state of disrepair. The proposed expansion of the coal industry has resulted in negotiations for a substantial upgrading of rail facilities. This could include double-tracking, and route relocation where this can be shown to be desireable.


Surficial Geology
See attached text for legend.
Scale 1:50,000
N
MOOSE VALLEY
KOKANEE
GOAT RANGE
Rainbow Cr.
Cutthroat Creek
Pristine Lake
SHEEP RIDGE
PINE FLATS
Fisherman's Lake
DEER HILLS
RIVER
Short Line RR.
Trans-Canada Highway
Tunnel
Coalville Stn.
Coalville
To Port
1200
1400
1600
1800
2000
2200
2400
$Ev/sLt-VP
$Mb//Cv
gFt/Ovb-E
gFt/$L-F
$Ev/$Lt-VP
Rsh//Cv-AK
$Lt/$Ev/$Lt-VP
Cvb=Rs
c$Mb//Cv
gFt//gMb
gFt/$L-F
$F^A_v/sgF^A L / Ov/Fl - E^A
gFt
gF^G_h
gF^G_h/$Lb
Cvb//Rs-A
gF^G_t/Mb-E
c$Mb//gMv
gsF^A
s$Mb
$rCv=Rs-A
R
Mb/Cv
gF^A-E^A
sF^A
$rCv=Rs-A
Mb/Cv
s$Mb
r$Chr
gFl
$rCv/R-F
gFt
Mb/Cv
Mb

EXAMPLE OF TERRAIN UNIT SYMBOL



A blanket of sandy fluvial silts overlying coarse fluvial deposits in an active floodplain environment in which deflation (removal of fines by wind action) is taking place.

1. Texture

SPECIFIC CLASTIC TERMS (Wentworth)		COMMON CLASTIC TERMS		ORGANIC TERMS	
b	bouldery	a	blocky	e	fibric
k	cobbly	r	rubbly	m	mesic
p	pebbly	g	gravelly	h	humic
s	sandy	f	fines		
$\not{s}$	silty				
c	clayey				

2. Genetic Material

Materials are classified according to their mode of formation. Specific processes of erosion, transportation, deposition, mass wasting and weathering produce specific types of materials that are characterized chiefly by texture and surface expression.

A	Anthropogenic	O	Organic
C	Colluvial	R	Bedrock
E	Eolian	S	Saprolite
F	Fluvial	V	Volcanic
I	Ice	W	Marine
L	Lacustrine	U	Unconsolidated
M	Morainal		

3. Qualifying Descriptors

A number of descriptors have been introduced to qualify either the Genetic Materials or the Modifying Process terms. These are denoted by an upper case superscript following the term so qualified.

The descriptors qualify:

1. The clastic genetic material or modifying process terms, and are used to supply additional information about their mode of formation and/or depositional environment.

2. The organic genetic materials by classifying them on the basis of microrelief, height of water table, and vegetative origin. Where these qualifying descriptors are omitted, it indicates uncertainty or lack of data about the genesis of the organic deposit.

3. The status of the Genetic and Modifying processes. Included in the definitions of the Genetic Materials and Modifying Processes categories are statements concerning the commonly assumed status of their processes. Where the process status is contrary to the common assumption, it will be indicated.

DESCRIPTIVE TERMINOLOGY

1. Clastic: ^{G}Glacial.
2. Organic: ^{B}Bog; ^{F}Fen; ^{S}Swamp.
3. Process: ^{A}Active; ^{I}Inactive.

4. Surface Expression

The surface expression of genetic materials is their form (assemblage of slopes) and pattern of forms. It also expresses the manner in which unconsolidated genetic materials relate to the underlying unit.

DESCRIPTIVE TERMINOLOGY

a	apron	m	subdued
b	blanket	r	ridged
f	fan	s	steep
h	hummocky	t	terraced
l	level	v	veneer

5. Modifying Processes

Terms which describe those geological processes that have modified or are currently modifying genetic materials and their surface expression.

DESCRIPTIVE TERMINOLOGY

-A	Avalanched	-K	Karst Modified
-B	Bevelled	-N	Nivated
-C	Cryoturbated	-P	Piping
-D	Deflated	-S	Solifluccted
-E	Channelled	-V	Gullied
-F	Failing	-W	Washed
-H	Kettled		

OTHER SYMBOLS

1. Composite Units

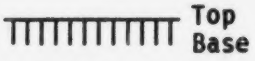
Not all terrain can be presented as simple units since terrain units commonly occur that are of small areal extent and cannot be delimited individually at the scale of the mapping. Consequently, a system of composite units is employed whereby up to three types of terrain may be designated within a common unit boundary. The relative amounts of each terrain type are indicated by the use of the symbols =, /, and //. The components are always indicated in decreasing order of abundance.

= components on either side of this symbol are approximately equal

/ the component in front of the symbol is more abundant than the one that follows

// the component in front of the symbol is considerably more abundant than the component that follows

2. On-Site Symbols

Escarpment 

Wind dunes (inactive)

CLIMATIC INFORMATION

The climate of the project area is classified as continental sub humid at low elevations and continental cold humid at higher elevations. Approximately three years of data is summarized in the following table:

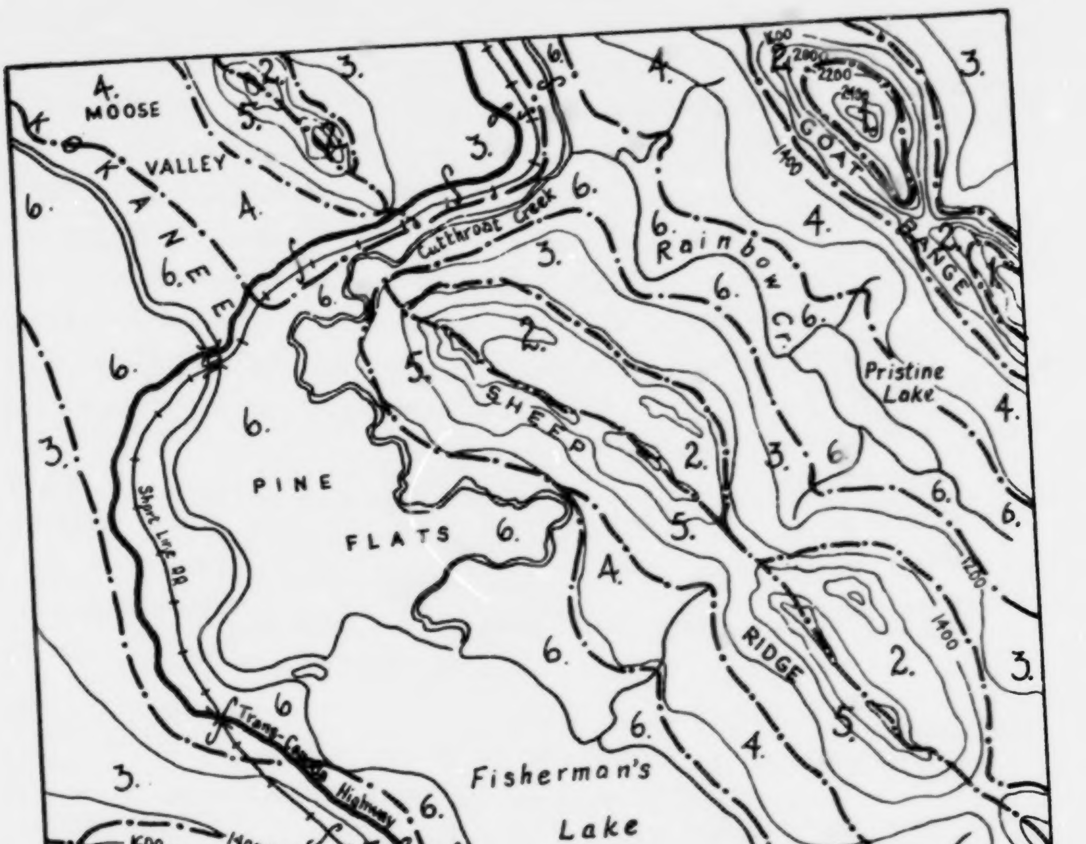
	Station	
	Coalville	Sheep Ridge
Mean monthly temperature	4°C	0°C
Mean January temperature	-11°C	-13°C
Mean July temperature	15°C	12°C
Months above 10°C	3	2
Months above 5°C	5	4
Months below 0°C	5	6
Frost free period (days)	90	61
Total precipitation (cm)	71	93
Annual snowfall (cm)	312	720
Occurrence of precipitation		
wettest season	winter (40%)	winter (38%)
wettest month	January	January
driest season	fall (18%)	summer (18%)
driest month	October	May

VEGETATION

Two biogeoclimatic zones (Krajina 1964) occur in the study area; the interior Douglas fir zone at elevations from 1100 m to approximately 1500 m, the Englemann spruce-subalpine fir zone from 1500 m and the alpine tundra above 2100 m. Within these three zones are six distinct vegetation types that can be summarized as follows:

1. Alpine
    - mosaic of bare rock and alpine tundra communities composed of grasses, sedges, and forbs.

2. Subalpine forest
    - climax forest composed of subalpine fir, Englemann spruce, whitebark pine, lodgepole pine
    - understory composed of shrubs (kinnikinnik, false azalea,



MOOSE
VALLEY
OKANEE
Cutthroat Creek
Rainbow Cr.
GOAT RANGE
Pristine Lake
SHEEP
RIDGE
PINE
FLATS
Short Line RR
Trans-Canada Highway
Fisherman's
Lake
DEER
HILLS
RIVER
Coalville Stn.
Coalville
To Port
1200
1400
1600
1800
2000
2200
2400
Vegetation Map
1 Alpine communities
2 Sub-alpine forest
3 Seral coniferous forest
4 Seral mixed forest
5 Sub-climax grass-shrub
6 Floodplain communities
N
Scale 1:50,000

white rhododendron, grouse berry) and scattered grasses, sedges and forbs.

3. Maturing seral coniferous forest
   - seral community resulting from extensive wildfires approximately 35 years ago
   - forest of western larch, Douglas fir, lodgepole pine, trembling aspen
   - sparse understory of shrubs (Douglas maple, Saskatoon, Oregon grape, chokecherry, willow). The main ground cover is pine grass.

4. Maturing seral mixed forest
   - seral community resulting from extensive wildfires approximately 35 years ago. Differs from 3. in the development on drier southerly aspects
   - tree component consists of aspen, paper birch, Douglas fir, lodgepole pine and Rocky Mountain juniper
   - the understory is very rich consisting of many forb species, bluegrasses, fescues, bunchgrasses and the shrubs Douglas maple, Saskatoon, Oregon grape, chokeberry, wild rose, willow and kinnikinnik.

5. Sub-climax grass-shrub community
   - this is a stable, near-climax community due primarily to the southerly aspect and the coarse textured kame terrace on which it is situated. These two factors combine to make these slopes too dry to support tree growth
   - the shrub component consists of Douglas maple, Saskatoon, Oregon grape, kinnikinnik, sticky laurel, willows, blue elder, soopolallie
   - ground cover consists of bunchgrasses, fescues, bluegrasses and a forb component of rich species diversity
   - this plant community is unique in British Columbia, being

more closely related to some of the grasslands east of the continental divide in the southern Rocky Mountain foothills.

6. Floodplain communities
    - this unit is a mosaic of vegetation types resulting from the action of both periodic flooding and past wildfire
    - the tree component consists of white spruce, black cottonwood, paper birch, trembling aspen
    - the shrub component consists of alder, red-osier dogwood, Columbian hawthorn, silver berry, wild rose and various willows
    - drier areas support grass-forb communities of considerable diversity; wetter areas support sedge meadows and marsh vegetation.

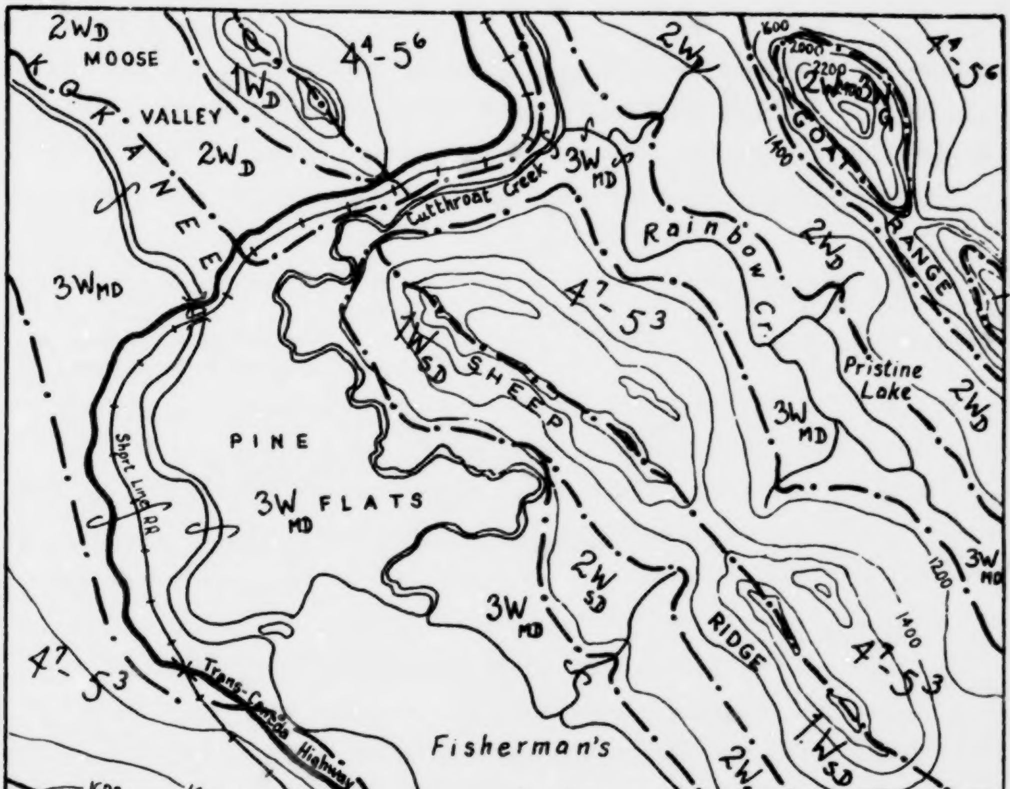
WILDLIFE

From a wildlife perspective the Coalville area is known chiefly for its wild ungulate populations. Within the area to be affected by mining are moose, mule deer, mountain goat and Rocky Mountain bighorn sheep. The current status of each of these species is summarized below:

1. Moose

Moose are a relatively recent arrival in this area, having gradually spread northwards from the United States. Present population in the area is about 300 which, in strictly numerical terms, represents an insignificant proportion of the provincial population. The major importance of this population is genetic in that this is the Yellowstone moose, an entirely different subspecies than is present in the rest of the province.

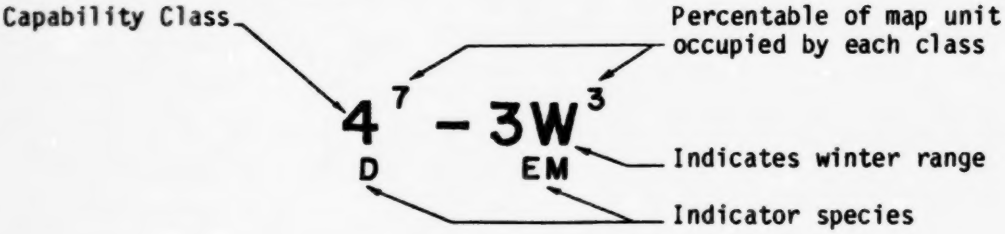
Moose use the Kokanee, Cutthroat and Rainbow valley floodplains in winter, moving to higher elevations in the summer. Considerable scope exists for habitat enhancement since many of the shrub


2W$_D$
MOOSE
VALLEY
KOKANEE
1W$_D$
4^4-5^6
2W$_D$
3W$_{MD}$
Cutthroat Creek
3W$_{MD}$
2W$_D$
1600
2000
2200
2W$_D$ 3W$_G$
1400
GOAT RANGE
4^4-5^6
Rainbow Cr.
2W$_D$
2W-3W$_G$
4^7-5^3
1W$_{SD}$
SHEEP
Pristine Lake
2W$_D$
3W$_{MD}$
PINE FLATS
3W$_{MD}$
Short Line RR
1200
3W$_{MD}$
2W$_{SD}$
3W$_{MD}$
RIDGE
1400
4^7-5^3
1W$_{SD}$
4^7-5^3
Trans-Canada Highway
Fisherman's Lake
2W$_{SD}$
1600
1400
1900
$2W^4-3W^6_D$
DEER
Tunnel
HILLS
RIVER
4^7-5^3
3W$_{MD}$
Wildlife Capability
See attached legend.
Coalville Stn.
Coalville
N
1200
To Port
$2W^4-3W^6_D$
4^7-5^3
Scale 1:50,000

KEY FOR INTERPRETATION OF UNGULATE CAPABILITY MANUSCRIPT MAPS (B.C.)

There are 7 capability classes based on the ability of the land to support or produce wild ungulates. The capability class level is determined by the degree of limitation which affects the quality and/or quantity of habitat for the animals.

Example Classification



a. Capability Classes

Class 1 - No limitations to the production of ungulates.
Class 1W - Extremely important winter range for ungulates.
Class 2 - Very slight limitations to the production of ungulates.
Class 2W - Very important winter range for ungulates.
Class 3 - Slight limitations to the production of ungulates.
Class 3W - Important winter range for ungulates.
Class 4 - Moderate limitations to the production of ungulates.
Class 5 - Moderately severe limitations to the production of ungulates.
Class 6 - Severe limitations to the production of ungulates.
Class 7 - Such severe limitations that almost no ungulates are produced.

b. Species

A - Antelope
C - Caribou
D - Deer
E - Elk
G - Goat
M - Moose
S - Mountain Sheep

stands in the riparian winter range have grown beyond the reach of the animals.

The present population provides both hunting and viewing opportunities for local residents. An increase in hunting harvest of about 1/3 could be sustained at present levels of management. About 10-20 animals are killed every year through collisions with trains and road vehicles.

2. Mule deer

Mule deer winter in the seral mixed forest communities on south-facing slopes throughout the area. Populations peaked about 15 years ago at approximately 900 animals and have subsequently declined to about 550 animals due to advancing succession on these ranges. The population supports most of the local hunting activity, however, with optimum habitat management, could sustain 2-3 times present hunting levels.

During heavy snow years considerable mortality occurs along the railway on Deer Hills Plateau due to collision with trains.

3. Mountain goat

A population of about 30-40 goat inhabit the rocky alpine ridges of the Goat Range. Hunting pressure is currently very low because of a lack of road access in the Rainbow Creek valley. Goat are commonly seen by backpackers and climbers visiting the area during summer.

4. Rocky Mountain bighorn sheep

The south-facing grass-shrub communities on Sheep Ridge currently winter approximately 250 bighorn sheep. This population is of provincial significance for two reasons: first, it represents approximately 5% of the total provincial population of bighorn sheep; and second, it is the only herd that did not decline during a mysterious "die-off" that occurred in the southern part of the province approximately 15 years ago. The reason for this herd's immunity is not known. Both genetic differences and geographical isolation are suggested, however, other herds as isolated declined in number by as much as two thirds.

The population is currently fully utilizing its existing range and very little scope exists for range improvement through habitat enhancement. Hunting is restricted to full-curl rams and current pressure is modest. A significant increase in hunter demand would, however, require more stringent regulation. The relative accessability of the herd provides significant viewing opportunities, particularly during late winter and early spring.

Some evidence exists to suggest that the grass-shrub community on the northeast side of Moose Valley may have once supported bighorn sheep, however, no animals have ever been seen on this range.

FISHERIES

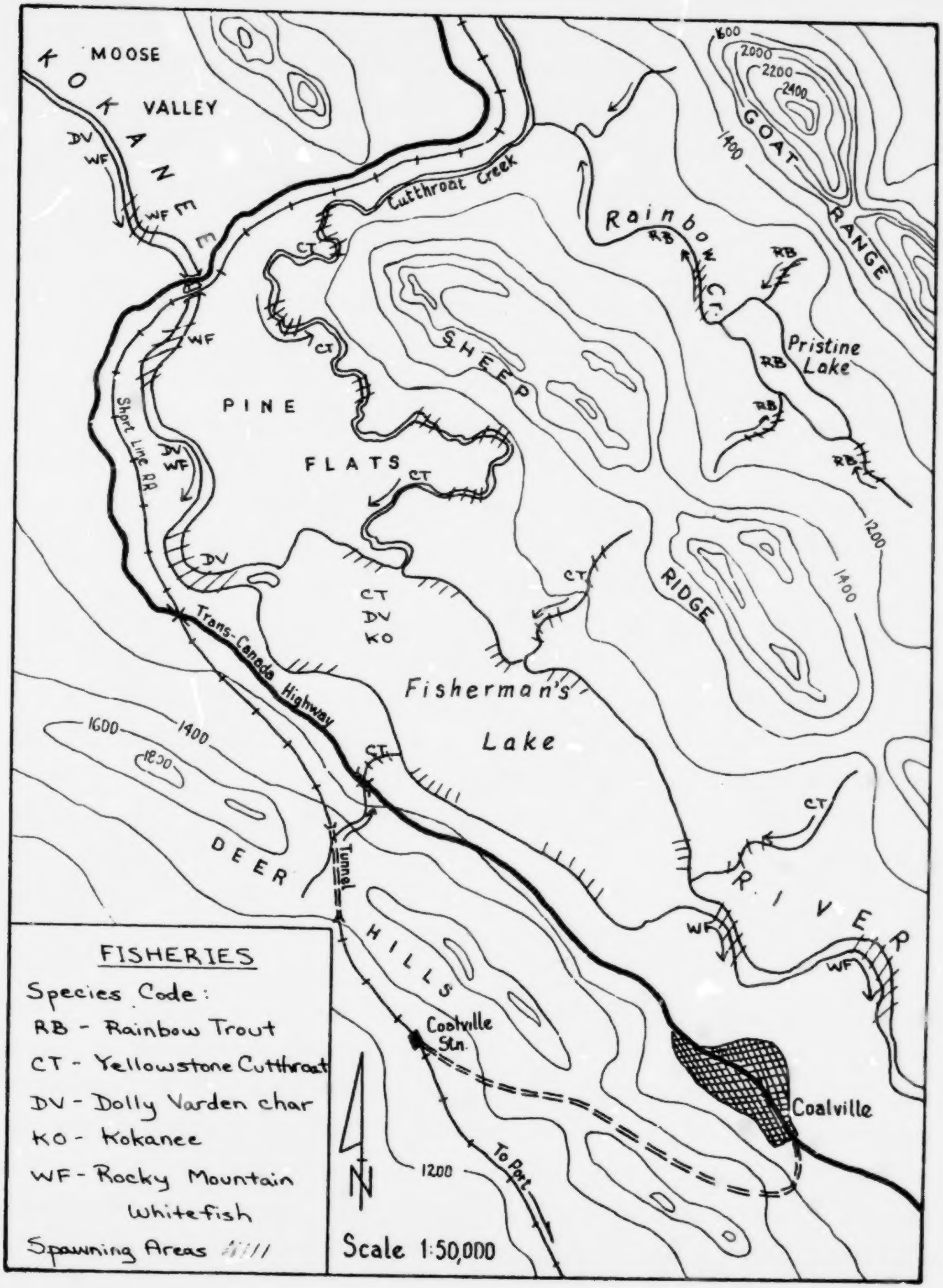
The streams in the Coalville area support populations of Yellowstone cutthroat trout, rainbow trout, Dolly Varden char, Kokanee salmon, and Rocky Mountain whitefish. The habitat utilization of the streams and lakes in the area by each of the species is summarized below:

1. Rainbow Creek and Pristine Lake

   Rainbow trout spawn in Rainbow Creek and the tributaries to Pristine Lake in the spring. Upon emergence in the summer, the rainbows move immediately into Pristine Lake to rear. Since there is no road access into the area, the lake presently supports a local, low pressure fishery.

2. Cutthroat Creek

   Yellowstone cutthroat trout spawn in both Cutthroat Creek and in the minor tributaries to Fisherman's Lake. Spawning occurs in the


MOOSE
VALLEY
KOKANEE
DV
WF
WF
Cutthroat Creek
CT
CT
WF
PINE
FLATS
CT
Short Line RR
DV
WF
DV
SHEEP
RIDGE
Rainbow Cr.
RB
RB
Pristine Lake
RB
RB
RB
GOAT RANGE
1600
2000
2200
2400
1400
1200
1400
CT
CT
DV
KO
Trans-Canada Highway
Fisherman's
Lake
CT
CT
1600
1400
1800
DEER
HILLS
Tunnel
RIVER
WF
WF
Coalville Stn.
Coalville
To Port
1200
N
Scale 1:50,000
FISHERIES
Species Code:
RB - Rainbow Trout
CT - Yellowstone Cutthroat
DV - Dolly Varden char
KO - Kokanee
WF - Rocky Mountain Whitefish
Spawning Areas ////

spring, and the trout rear in the creeks for two to three years before moving into Fisherman's Lake. Cutthroat Creek is heavily fished by both residents and non-residents. Rearing habitat in the creek is critical, and the Yellowstone cutthroat population could not sustain increased fishing pressure under the present levels of management.

3. Kokanee River

   Both Dolly Varden char and Rocky Mountain whitefish spawn in the Kokanee River in the fall. The Dolly Varden spend from several months to three to four years in the river before moving into Fisherman's Lake, and the whitefish are life-long residents of the river. Fishing pressure in the Kokanee River is moderate, and the Dolly Varden and whitefish populations are capable of sustaining higher angling pressure if the habitat is optimally managed.

4. Fisherman's Lake

   Kokanee salmon spawn at select shoreline areas of Fisherman's Lake in the fall. The lake supports resident populations of Yellowstone cutthroat trout, Dolly Varden char, and Kokanee salmon, and a regionally and provincially significant sport fishery. Fisherman's Lake is capable of supporting higher numbers of all three fish species, however, critical rearing habitat in Cutthroat Creek is a limiting factor for Yellowstone cutthroat production. Fishing pressure in the lake is currently high.

It is anticipated that the population of Coalville will double if the new mine goes into production. This population expansion would likely result in increased fishing pressure in the above watersheds, therefore alterations to the management techniques presently utilized may be necessary. To assist with future fisheries management decisions, the current fishing regulations for the area follow: Kokanee River (tributary streams only). Angling closure October 1 to June 15.

	Daily Limit	Possession Limit
Aggregate trout and char over 50 cm, fork length	2	4
Aggregate trout and char, all sizes	8	24
Kokanee over 50 cm, fork length	2	4
Aggregate Kokanee, all sizes	15	30
Whitefish	25	75

PRESENTATION OF THE ANNUAL
RECLAMATION AWARD

March 6, 1980

RECLAMATION AWARD

As in past years nominations were solicited by Tony Milligan, Chairman of the Technical and Research Committee on Reclamation. The awards and citations, under the auspices of the British Columbia Ministry of Energy, Mines and Petroleum Resources and the Mining Association of British Columbia, have been established to recognize achievement in reclamation. The major award is for outstanding achievement in mine reclamation. In addition, three citations are presented for merit in mine reclamation. The citations are awarded in three categories:

1. Mine exploration
2. Metal mining (including gravel, quarries and placer)
3. Coal mining

The Terms of Reference governing the preparation of nominations for this year's awards are identical to those presented in the proceedings of the 1979 Reclamation Symposium.

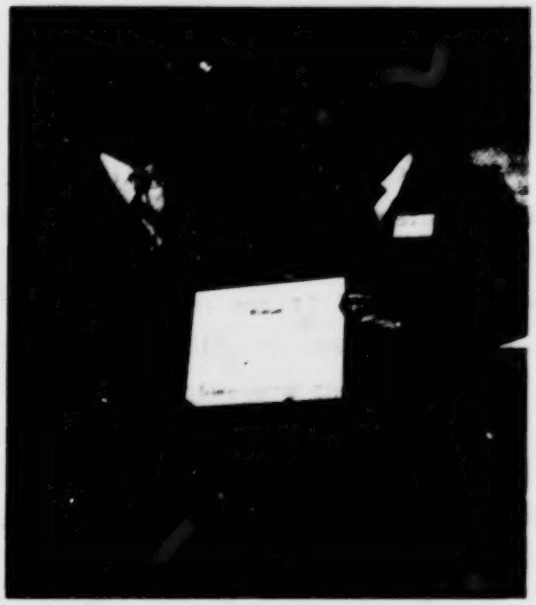
The awards were given in the following order:

Citations:

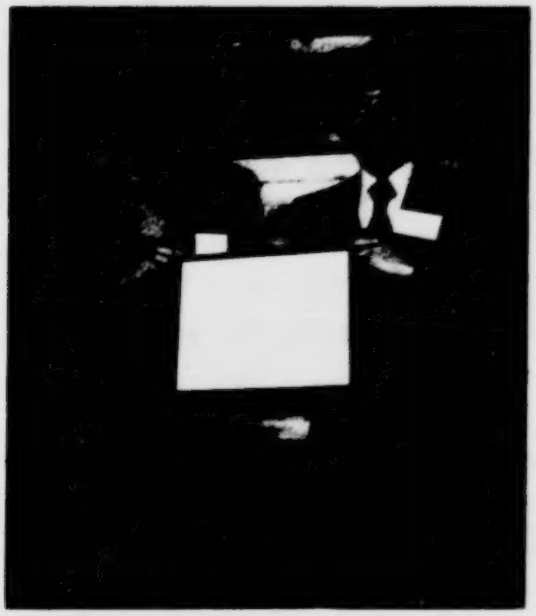
1. Mine exploration
2. Metal mining
3. Coal mining

Major Award - to be retained for one year and then returned at next year's meeting.

This year a number of companies were nominated for awards in each category. The scope and quality of reclamation work performed by all nominees, made the task of the Awards Committee particularly difficult.



Nick Agnew (left) and Dick Marshall accepted the reclamation citation for exploration on behalf of BP Exploration Canada Ltd.



Ron Hills (left) and Clem Pelletier accepted the reclamation citation for metal mining on behalf of Island Copper.

CITATIONS

1. Mine exploration

The 1979 citation for mine exploration is presented to:

British Petroleum Exploration Canada, Ltd.

British Petroleum has demonstrated a strong commitment to reclamation of disturbances on their Sukunka coal property in the northeast. Not only have they demonstrated vegetation establishment success but also in project planning. They have been cognizant of environmental sensitivities and have taken positive action toward environmental protection.

Honorable mention is given to:

Ranger Oil (Canada) Ltd.
- Mount Spieker Coal Property

Silver Standard Mines
- Tyaughton Creek Access

2. Metal mining

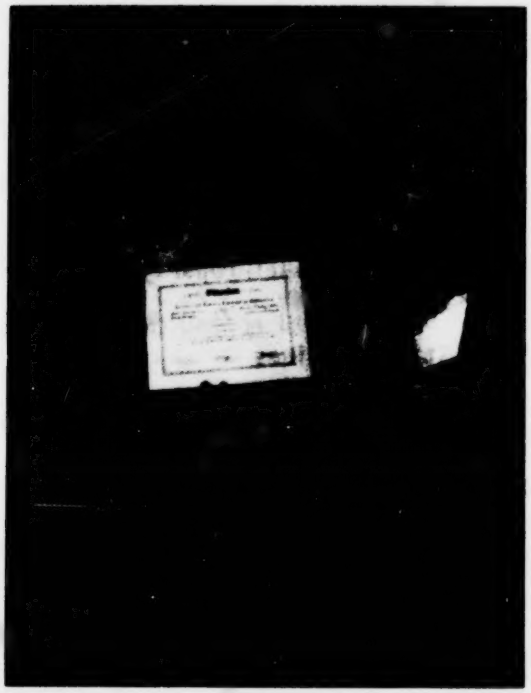
The 1979 citation for metal mining is presented to:

Island Copper

Island Copper (Port Hardy, B.C.) have recontoured 25 hectares and have established vegetation on 67 hectares. Success has been achieved with both agronomic and native species, and they have successfully used alder, a nitrogen fixing species, in reclaiming land areas. Careful planning has allowed continual and progressive reclamation.

Honorable mention is given to:

Newmont Mines, Ltd.
- Similkameen



Ricci Berdusco (left) and Tony Milligan accepted the coal mining Reclamation Award on behalf of Kaiser Resources Ltd.

3. Coal mining

The 1979 citation for coal mining is presented to:

Kaiser Resources Ltd.
- Sparwood

Kaiser Resources, last year's winner of the Reclamation Award, receives the citation for their continued excellence in mine reclamation. Kaiser Resources have resloped, terraced and successfully vegetated slide and rock dump areas; they are also conducting some of the most significant research in mine reclamation in British Columbia. Research has been conducted in the:

- rate of rehabilitation of reclaimed areas,
- effects of fertilizers,
- study of soil microbiology (a first in British Columbia),
- effects of nitrogen fixation and distribution.

Honorable mention is given to:

Byron Creek

Roger Berdusco (left) and Dermot Land accepted the 1979 Reclamation Award on behalf of Fording Coal Ltd.

RECLAMATION AWARD

The 1979 Reclamation Award is presented to:
Fording Coal Ltd.
- Elkford, B.C.

Fording Coal has demonstrated a positive approach to the development and application of conservation and reclamation technology designed to protect and rehabilitate land and watercourses within the Fording Valley. They have restored abandoned exploration roads to near-original slope prior to revegetation and have undertaken surface soil conservation for subsequent reclamation use. The company has an ongoing research program to study optimum spoil dump angles and the use of overburden in reclamation; and through their new greenhouse and nursery facilities, are investigating vegetation techniques to advance both the theoretical technology and practical field aspects of reclamation.

ESTABLISHMENT
OF
VEGETATION

Chairman of the Morning Session
Friday March 7, 1980

A. Lamb
Interior Reforestation Ltd.
Fort Steele, B.C.

USE OF AGRONOMIC SPECIES
IN MINE RECLAMATION

Paper presented

by

Angus S. Richardson, P.Ag.
General Manager
Richardson Seed Company Limited
Burnaby, British Columbia

USE OF AGRONOMIC SPECIES IN MINE RECLAMATION

INTRODUCTION

Agronomic is the nomenclature given to plant species that, over time, have become domesticated native species; therefore, the term distinguishes a plant from a current native plant. For this discussion I have included all commercially harvested seed crops of grasses and legume species.

The purpose of establishing grass and legumes on a reclamation site is:

- to revegetate a disturbed area,
- to provide forage for native or domestic animals,
- to provide surface erosion control,
- to provide esthetic satisfaction, and
- to provide a cash crop for income where feasible.

In the first four objectives a satisfactory ground cover is what is being sought, rather than an agricultural income from the forage. With the former in mind, we must concern ourselves with the choice of the agronomic species for seeding, since the choice is between:

- the common seed types which have a wide genetic base, and
- the selected seed variety with a narrower genetic base.

The majority of plant breeders select varieties capable of providing high agricultural yield under good soil conditions. Such varieties often have high nutritional requirements and must be carefully selected for a specific situation. However, when disease threatens an area, or winter hardiness is a necessity, then varieties having these attributes can benefit the reclamation situation.

In British Columbia, common seed, which is closest in origin to the original native material, is used because it has the widest genetic base and is adaptable to variable soil types and climates. In selecting common seed it is important that the origin of the plant be known, in order to determine if the plant will adapt successfully to the area where it is to be sown. Recently, importations of wheatgrass and alfalfa from Argentina have been introduced into Canada, an origin that would not be suitable for use in British Columbia.

THE CANADA SEEDS ACT

This Federal Act, administered by the Plant Products Division of the Food and Marketing Branch, Agriculture Canada, describes the conditions under which all seeds can be sold. The Seeds Act specifies what information must be provided to describe the seed, which must then be given to the buyer. By means of grade tables the Act specifies how clean the seed must be; how many weeds, if any, are allowed; and the minimum germination rate that a seed must have. Seed is thereby classified as Canada No. 1, Canada No. 2, or Canada No. 3. The Seeds Act also describes which species of grasses and legumes can be sold in Canada, and which varieties are licensed for sale in Canada. Many of the so-called "native species" of seed cannot be sold under the terms of the Seeds Act, and special permission for the use of such species must be obtained from Ottawa.

PRINCIPLES OF SEED MIXTURE DESIGN

Because soils are not always homogeneous and weather patterns do not repeat themselves consistently, there is a distinct advantage in using a seed mixture that has been blended to suit the variables of the site. The following considerations are applicable to seed mixture design:

- The seed must be adapted to the climate and soils of the area.
- The seed must be adapted to the end use of the land and the desired longevity of the stand.
- The mixture must be economically viable.
- The mixture must be balanced:
  a. the plants should be able to withstand competition from one another (bio-compatability),
  b. it is usually desirable to blend legumes with grasses,
  c. enough seed of each major ingredient should be included to establish a stand if some species fail,
  d. the formulation expressed as a percentage of ingredients by weight, must reflect the desired percentage of ingredients by seed count, ie. end plant population. See following example calculations:

EXAMPLE: End Plant Population

Purity % (Weight)		Seeds/Pound		Seeds/Pound in Mix
25% Smooth Brome	X	125,000	=	31,250
25% Canada Bluegrass	X	2,500,000	=	625,000
25% Creeping Red Fescue	X	600,000	=	150,000
10% Timothy	X	1,300,000	=	130,000
5% Red Top	X	5,000,000	=	250,000
10% White Clover	X	800,000	=	80,000
				1,266,250

  e. consideration must be given in the formulation for the rate of establishment and germination of each kind of seed.

SPECIE AVAILABILITY AND ADAPTATION

Because agronomic species are principally used in agricultural situations, adequate inventories are maintained and planned production as seed crops is undertaken, so there is seldom a serious shortage of seed. During certain years when drought prevails or bad weather is experienced at harvest time, certain shortages can occur. If any reclamation user is concerned about seed availability, contract arrangements can be made with any seed merchant to produce his requirements to ensure a supply. Classification of species normally available, subclassified as to their end adaptation, is given below:

1. Rapid Developing, Short-Lived Grasses

Humid Areas: Annual Ryegrass (sometimes called Common or Italian)
Westerwolds Ryegrass

Dryland Areas: Slender Wheatgrass
Tall Oatgrass

2. Rapid Developing, Long-Lived Grasses for Sub-Humid and Irrigated Areas

Orchardgrass
Intermediate Wheatgrass
Tall Fescue
Smooth Bromegrass
Perennial Ryegrass (Diploid and Tetraploid)

3. Drought Tolerant, Long-Lived Bunch Grasses

Crested Wheatgrass
Bluebunch Wheatgrass
Big Bluegrass

Slow to Establish
Hard Fescue
Russian Wild Ryegrass
Tall Wheatgrass

4. Drought Tolerant, Long-Lived Sod Grasses

Pubescent Wheatgrass
Kentucky Bluegrass
Streambank Wheatgrass
Red Top
Canada Bluegrass
Creeping Red Fescue

5. Saline and Alkali Tolerant Grasses

Tall Wheatgrass
Crested Wheatgrass
Russian Wild Ryegrass
Streambank Wheatgrass
Creeping Foxtail
Slender Wheatgrass
Tall Fescue

6. Acid Tolerant Grasses

Red Top
Red Fescue
Creeping Bentgrass
Meadow Foxtail
Colonial Bentgrass
Hard Fescue
Canada Bluegrass
Tall Fescue

7. Dense Deep-Rooted Grasses

Crested Wheatgrass
Orchardgrass
Intermediate Wheatgrass
Russian Wild Ryegrass
Hard Fescue

8. Dense Shallow-Rooted Grasses

Red Top
Canada Bluegrass
Kentucky Bluegrass
Creeping Bentgrass
Creeping Red Fescue

9. Fine Leaved Multi-Purpose Grasses

Kentucky Bluegrass
Chewings Fescue
Creeping Red Fescue
Hard Fescue
Canada Bluegrass

10. Wet Land Grasses

Meadow Foxtail
Timothy
Red Top
Reeds Canarygrass

11. Legumes

Alfalfa
Sweet Clovers
Alsike Clover
White Clovers
Sainfoin
Red Clovers
Bird's-foot Trefoil
Cicer Milk Vetch

12. Special Agronomics

Bearded Wheatgrass
Alaska Brome
Siberian Wheatgrass
Thickspike Wheatgrass
Blue Wild Rye
Basin Wild Rye
Beardless Wheatgrass
Big Bluegrass
Mountain Brome
Alkali Sacaton
Harding Grass
Upland Bluegrass

SEED APPLICATION RATES

The application rate for seed to be used in reclamation in British Columbia is determined by the following factors:

- strength of establishment required,
- seed bed preparation,
- soil temperature (time of seeding),
- soil moisture,
- method of application,
- ingredients in seed mixture,
- companion crop.

As a rule of thumb in the dryer areas of the Province, less seed is used than in the moist areas. When agricultural equipment is used, a seeding rate of 30 - 75 lb/acre is used. When hydro-seeding is the method of application, the seeding rate is usually increased by 25%. When seeding is carried out by aircraft, the seeding rate is increased by 50%.

COATED SEED

Coated seed, a relatively new product, is being promoted, therefore it warrants a few comments. Coated seed originated in New Zealand where much of the seeding on native ranges is done by aircraft. The ballistic weight of the coating material to the seed has benefit in this situation. When the seed is coated, the product becomes:

In grasses: 50% of the weight is seed, 50% is coating material
In legumes: 66% of the weight is seed, 34% is coating material

The coating usually used for grasses is a lime based polymer with approximately 5% available nutrients. This means that when the entire product is applied at 50 lb/acre, 1-1/2 pounds of actual plant food is applied per acre. In legumes, the coating is usually a humus-lime mix containing the correct strain of rhizobia bacteria.

The benefits of coated seed are as follows:

- price per pound of the seed mixture is reduced,
- the specific weight of the seed is increased,
- there is marginal nutrient benefit,
- the coated seed usually withstands deeper planting than raw seed.

The disadvantages of coated seed are as follows:

- in grasses, you only get half as many actual seeds per pound, compared to raw seed;

- coating usually reduces the germination of the seed;
- costs per acre are much higher;
- product is difficult to handle and, generally does not flow very easily;
- coated seed is not as readily available as ordinary seed.

During an initial trial period with coated seed, the Richardson Seed Company has supplied over 100,000 lbs. of the product to the industry, and generally, the feedback we have received has indicated disappointing results. We are of the opinion that to achieve the most economical and satisfactory results, raw seed should be used wherever possible. Only in site-specific situations do we see a place for coated seed, such as the benefits of having the extra ballistic weight around the seed.

SEED PRODUCTION

British Columbia imports, either from the United States, or from other regions of Canada, most of the seed used within the Province. As indicated earlier, it is important that the origin of the seed to be used should be adaptable to B.C. conditions. Seed merchants aware of local agronomic conditions, comply accordingly. The following list shows the commonly used species, complete with their most common source of origin:

LEGUMES

Alfalfa: Idaho, Washington, Southern Alberta
Alsike and S.C. Red Clovers: Peace River, Saskatchewan
White Clover: B.C., Idaho, Oregon, New Zealand

GRASSES

Creeping Red Fescue: Peace River
Wheatgrasses: Alberta, Saskatchewan, South and North Dakota, Montana
Orchardgrass: Oregon, Southern Alberta
Ryegrass: Oregon

Timothy: B.C., Alberta, Saskatchewan, Manitoba, Minnesota
Bluegrass: Washington
Red Top: Mississippi, Poland, B.C., and the Prairies Provinces

DISCUSSION RELATED TO A. RICHARDSON'S PAPER

Art Bomke - University of British Columbia: I've read somewhere that the coating of legume seeds with lime has a beneficial effect on the survival of rhizobium. It could be significant in the acidic materials we're trying to vegetate. Can you tell us something about that?

Answer: I think the coating of legumes is generally more acceptable and more widely practised than is the coating of grasses. Of course, the legume seed is always coated to some degree with the rhizobia; but in what I call the "coating process", we get a definite coat containing the rhizobia around the seed. There are many people using the coated legume product. It was used extensively in Ontario last year, and it has also been used in California. I think that there may be some real benefits to coating legumes this way; but at the present time, the general concensus by farmers is that the coating is perhaps not giving them any greater benefits than they had before. The other interesting thing is the introduction of newer rhizobia strains that may allow us to get better innoculation of our legumes and consequently more nutritional benefits.

Duane Johnson - Hardy Associates Ltd.: We tested coating winter seed in the Arctic and found there were many problems with fungal infestation. I was wondering if you have had any experience with that?

Answer: I, personally, have not. We have not worked in the Arctic and I have not heard of the problem of increased fungal attack. But we have had experience sowing the coated seed in the late fall of the year, just before the snow came in, and waiting for spring germination. In those instances we felt that we gained no benefit from the coated program. The idea basically was that it would be our "pop up" fertilizer, if you will; but it seems that one needs our fertilizer program. I'm sure coated seed will be used to a much wider extent, and there may yet be benefits which we still haven't seen in our coated seed.

Duane Johnson: Do you find that you coat all varieties of seed?

Answer: Coatings can be done on any species. It's just a simple matter of putting a solution around the seed. In legume innoculation, it's a little bit more difficult because the innoculant is only good for a certain period of time. Also, the seed is wrapped up in that coating, it's more difficult to reinnoculate it.

S. Parmar - B.C. Research: In the formation of seed mixtures we consider the number of seeds per pound. Don't you think it would also be good to consider the purity of the seed?

Answer: Sohan pointed out, and very rightly so, that in the formulation of seed mixtures, you should also consider the living seed aspects. What this really means is that some seeds will have a 90% purity because they are chaffy, whereas, other seeds will have a 99% purity because they have a very low chaff content. Additionally, some seed species will grow at 90% germination or 95% germination very easily and rapidly, whereas, with others, it is difficult to get them higher than perhaps 80%. So, you multiply the pure seed aspect with the germination to take this into account. Sohan, I chose to ignore that factor here because when you work the pure-living seed into the particular table I showed you, it will alter the percentage by about half to three quarters of a percent in the final instance. It's a rather complicated process, but it is an extremely useful point, and it is one we do consider in seed mixture design.

USE OF NATIVE SPECIES IN MINE LAND RECLAMATION

by

V.C. Brink
Plant Science Department
University of British Columbia

THE USE OF NATIVE PLANTS IN MINE LAND RECLAMATION

INTRODUCTION

Mankind has a basic and reasonable responsibility to maintain the potential productivity of earth's land surface and to recognize that solar energy harvested by plants is a prime basis of life support systems. As Man's disturbance and modification of the earth's surface increases, the topic to which we now address ourselves must also grow in importance.

There are however many in this audience, including our Chairman, who have had much more experience than I have in establishing plants on mine lands. I acknowledge at once that my interests have focussed on the establishment of plants for agricultural purposes, for amenity purposes such as golf and parkland, and for highway verges. I must admit to a largely general rather than specific interest in the establishment of plants on mine lands; over several decades my interest in mine land reclamation has met with considerable frustration and my background now seems fragmented and lacking coherence.

Of the now fairly extensive literature extant on the use of agronomic and native plants on lands disturbed by mining, I have partial knowledge but enough to know that it is largely non-quantitative, observational and empirical. There is little yet which is theoretical or predictive on the use of native plants. As Frank Egler, an applied plant ecologist of some renown in the United States repeatedly points out, vegetation science is in its infancy. I agree.

It is inevitable that agronomic or domesticated plants should offer the primary appeal in providing cover during mine land reclamation. The availability and cost of seed and the comparative ease of the agricultural method makes this so. When and where the goals are met with the use of domesticated plants, their use should be encouraged. Quite often, however, the objectives cannot be met or are only partially met by the use of agronomic species. As knowledge and sophistication grow, we should look beyond the present-day domestic gene pools and extend them to include the native plant gene pools.

PLANT ADAPTATION - GENETIC AND ENVIRONMENTAL

As almost everyone is aware, plants and animals are the product of their heredity and their environment. Thus there must be a primary concern with the adaptation of plants - through regard for their genetic constitution and the analysis of the mine land environment.

It is worth taking a few moments to review the enormous range of mine land environments in B.C. to which we expect plants to adapt. The mine land environments certainly exceed in diversity those we commonly think of as agricultural environments, although one has to admit that there are few environments on the globe today which man is not exploiting one way or another for food and/or fibre.

At Island Copper and Western Mines on Vancouver Island we are looking at cool marine west coast climates with precipitation of over 150 inches, with a long growing season, leached soils and an environment where native plants usually quickly cover any scars made by Man. On the other hand, at Tranquille where placers were worked over a century ago and precipitation is only 7 inches, the disturbed land is still much in evidence. Our mine lands are found from the 49th parallel in the Boundary Country to the 60th, near Atlin and, therefore, embrace considerable variation in day length and length of growing season. They exist from sea level on Texada Island to high alpine on, say, Poison Mt. in the South Chilcotin Mountains at 8,000 feet elevation, an environment where even under the best of circumstances plants establish very slowly indeed. Soil or edaphic conditions likewise range widely - from highly mineral and poor (oligotrophic) wet sites, to mineral rich (eutrophic) and dry and/or saline sites. Simply stated this means that in B.C. recommendations for mine land plantings, native or domestic, must almost always be site specific.

Goodman and Bray (1975) attempted a listing of features (physical, chemical and biological) of the lands disturbed by mining. These features, which often require special consideration, include: slope and aspect, wind effects, surface temperatures, water stress, stability of surface, nutrient status, spontaneous combustion, erosion, compaction, toxic substances, soil forming minerals and organic matter, and the soil flora and fauna. It is not that these factors are not encountered in establishing plants in agricultural and other contexts, but that the "ranges" or "amplitudes" met within the mine land context usually far exceed those in the agricultural or similar settings.

It is worthwhile to examine the originating sources of most agronomic species we use in mine land reclamation:

1. Virtually all of our agronomic species are herbaceous and are aliens; i.e. they originated not on this continent but on another often under climatic conditions only weakly analagous to our own.

2. In the introduction of these aliens to this continent, their distribution in their native land was usually not well considered. It is true that, even today after years of experience, our introductions represent limited provenances. This means of course that the genetic base of our introductions is quite limited. Much of the current agronomic testing continues to involve new introductions from countries of origin and includes attempts to build world or regional collections of species which have been used agronomically in our country for decades.

3. The genetic base of many agronomic species is probably narrowing because of the loss of wild or quasi-wild progenitors in the countries of origin. Breeding for adaptation for restricted purposes and areas narrows the genetic base by eliminating much

variability and selection for uniformity. Species used for mine reclamation, however, are often forage species and losses of genetic variations are probably less important.

4. Most herbaceous species used in mine land reclamation, unlike cereal species, have been domesticated only in recent centuries (alfalfa is an exception). Thus many are, genetically speaking, not far from being "wild" or "feral". It can be argued that in a land such as ours which was deglaciated within the last 20,000 to 30,000 years, these aliens constitute a welcome addition by diversifying a very youthful flora.

5. Many of our agronomic species without Man's direct assistance have "picked up" genes from congener native species after their introduction to our land. Timothy is a good example of a European species which, after it came to North America, picked up an inheritance once and possibly twice from our native timothy. This is also probably true of Kentucky bluegrass and many of our fescues and bentgrasses. To some extent we are now doing this sort of thing consciously. "Polar" bromegrass and perhaps "tundra" bluegrass, issued by the Alaska research station at Palmer, incorporates some genes from native species. In the case of "Polar" brome, genes from Bromus pumpellianus, a native species, were incorporated into domestic smooth brome (Bromus inermis), a brome originating in central Europe. Thus, "making" a "new" bromegrass which would be much more useful for high latitude environments (Klebesadel and Associates).

6. Most of the herbaceous species used in mine land reclamation are highly variable genetically and phenotypically. That is to say, the populations are highly heterozygous and individuals may respond in form and size in a wide array in different environments. Usually, too, the populations adapt to a wide range of microclimatic and microedaphic conditions. Thus smooth brome, an introduced species, may be found in environments from Mexico to

the Arctic and from the Atlantic to the Pacific; the same is true for many other alien agronomic species. Usually species used in reclamation and for forage are established as mixtures of species and strains to broaden the genetic base even further; usually far more plant material is used in establishment than can possibly survive and, thus, if one plant is not genetically suited to a given micro-area another with a different genetic base may be. Hundreds of millions of seeds may be scattered over a hectare in the expectation that only a few thousands will produce plants. (This is a strategy, incidentally, widely employed by certain plant species in nature.)

7. However, it should be recognized that agronomic species are continually being selected for their ability to yield well in a limited area, or for their ability to recover after mowing, or to give a quick canopy under conditions of more or less intensive agriculture; their genetic base and adaptability for survival under roughland conditions is being slowly reduced. Thus, some selections of alfalfa and of crested wheatgrass, just as examples, are doing fine in cultivation but very poorly on native ranges or on mine land reclamation areas which embrace many microclimatic and microedaphic conditions.

8. Seed production in some agronomic species is either low or of such a nature that a stand will not maintain itself in nature or under what is ecologically termed "old field" situations. The stand is therefore short lived and one is obliged to maintain it under quasi-agricultural conditions: continual reseeding, fertilizing, top dressing, etc. are required. Sometimes stands of introduced agronomic species, but not of comparable native species, are eliminated with dramatic suddenness - by pest, disease, drought, cold, etc. Sometimes the seed of agronomic species comes to our area from areas which are climatically far different to our own; certification of seed origin becomes a matter of great signifi-

cance (e.g. white clover seed from Louisiana, although often inexpensive, is usually unsuitable for B.C.).

9. Reference has already been made to the advantages of diversifying the flora of a recently deglaciated area such as our own by introducing species from other lands. It is just possible, too, that in diversifying the plant cover on disturbed areas whether mine land, range, roadside verges, logged-over lands, etc., the native fauna may also be diversified and perhaps enhanced or perhaps introduced fauna may be maintained. Examples are not hard to find. Chukar partridge, an introduced game bird, appears to survive in areas where downy brome, an introduced grass, is abundant.

INTRODUCTION OF NATIVE SPECIES

The introduction of native plant species in reclamation procedures may be viewed as the continuation of the long process of domestication of plants by Man for his special uses. It began in the stone-age when Man ceased to be strictly the hunter/gatherer and started to encourage the development of favored species by eliminating unwanted competitive species. It is a process which should be encouraged for I believe we can usefully employ a larger repertoire to meet the need for plants in a very wide range of environments in our province.

1. The repertoire may be expanded, in part, by scrutinizing new plant materials from other lands as is being undertaken at the Research Station of Agriculture Canada at Beaverlodge near the B.C./Alberta border in the Peace River area.

2. Adaptability of species and strains currently in use may be extended to some degree by hybridization of introduced and native species, as is being undertaken at the Alaska Agricultural Experiment Station, Palmor, Alaska.

3. There is much to be gained by scrutinizing our native species with a view to exploiting their usefulness in Man-modified habitats. The Soil Conservation Service of the U.S. Department of Agriculture has been doing this for many decades; some of the more active and valuable efforts have been at the Pullman, Washington station and its related stations by Drs. Hafenrichter and Schwendiman. From their efforts came useful strains of native grasses such as Whitmar Wheatgrass (Agropyron spicatum), Bromar Bromegrass (Bromus emarginatus (?)), Streambank Wheatgrass (Agropyron riparium), Big Bluegrass (Poa ampla) and others. Some seedhouses in the U.S. (e.g. Sharp & Co.) have selected strains of native shortgrass prairie and desert species such as Blue grama grass (Bouteloua gracilis) and Weeping lovegrass (Eragrostis sp.) which have been usefully employed in many amenity and reclamation projects.

4. Within our own provincial borders there may be value in scanning native plant materials with a view to exploiting them in reclamation and other Man-modified environments. I will name only one species, Altai Fescue (Festuca altaica). In introducing provenances from a species such as this for quasi-agronomic uses in our higher altitudes and latitudes, we might avoid costly long-term selections within existing agronomic species for increased cold and drought tolerance, adaptation to day length, etc.

In Britain, where very little plant cover remains which is truly native and/or climax, Smith & Bradshaw recently selected and issued for use in reclamation, strains of bentgrass and fescue which are tolerant of the somewhat toxic waste and tailings from hard rock mining. It may well be useful to scrutinize the plants growing on our own ultra-mafic parent materials (e.g. those in the Yalakom area which contain ferro-magnesium materials) with a view to locating strains tolerant to higher background levels of mercury or chromium. Plants too, in different ways, it may be recalled, do not necessarily reflect concentrations of the metals in the substrates and, may in fact, "screen out" as well as "screen in" elements. Scrutiny of native genotypes on calcareous parent materials (e.g. limestone mountains) or on some of the Tertiary lava parent materials (e.g. Cariboo-Chilcotin) might yield useful genotypes at no great cost.

CONCLUSION

I have often thought that it would be useful, particularly in B.C. with its many many varied near-micro environments, if all agencies interested in developing and maintaining a productive and useful plant cover over our province, could coordinate their efforts to clearly identify needs and set goals.

There are many common plant needs on the ranges, domestic stock and wildlife are often complementary as are those for highway verges, mine land and other roughlands. Singly, the needs are often minor, but collectively are often quite major. This conference could be a means of recognizing these interrelationships.

DISCUSSION RELATED TO V.C. BRINK'S PAPER

J. Dick - Ministry of Environment: Do you have any suggestions on how people might go about collecting herbaceous seed materials? I have heard some reports of this in surface mines in the U.S. using some kind of mini-combine harvester to harvest seeds from native swards. Collecting seeds from shrubs is fairly easy, but it's always been a formidable task trying to sample a sward where different plants are flowering at different times.

Answer: Well, quite honestly, I think the only way is to put in an intermediate step somewhere in order to make the initial collections, but you will always be quite limited. And then you harvest an area under pure-standing conditions. That's particularly true in British Columbia where the terrain is so rough. In the United States there are larger areas, and I think this would also be true of the prairie provinces, where you do find fairly pure stands. There is one point that might be of interest concerning the sweetgrass Paracloa Odorata or Paracloa Alpinum. They are both loaded with tumors and are highly unpalatable. to just about all of our native grazing ungulates. In talking to people at Banff National Park about this, we found that by including just a small amount of native sweetgrass in the verges along the Trans-Canada highway we were able to keep the elk off the highway and back in the trees. I didn't follow this up by researching the interrelationships between plants and wildlife. I think that some uses of native species could become important. In relation to the conservation of wildlife habitat, winter range area continues to decrease and this could be offset, to some extent, by revegetation with native grass species.

PROPAGATION OF NATIVE TREES AND SHRUBS FOR RECLAMATION USE

Paper presented

by

Doug Christie
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PROPAGATION OF NATIVE TREES AND SHRUBS FOR RECLAMATION USE

INTRODUCTION

The long-term final objective of a mine site reclamation program should be to produce a plant cover which is useful, aesthetically acceptable and self-maintaining. There are also very important interim objectives which include erosion control, slope stabilization and soil improvement. These depend very heavily upon the use of agronomic species, and, in general, I think that the mining industry has undertaken and carried out programs which effectively attain the interim objectives. Achievement of the final objective will depend very heavily on the use of native plant material.

Our programs of native plant establishment are much less advanced, and our experience in the establishment of permanent native plant cover on mine sites is, to date, incomplete. We do know, however, that future reclamation plans will have to make extensive use of native plant material. In order to do so, we must be able to propagate these native plants effectively and economically. Thus, it is important that we start out with the proper facilities.

THE PROPAGATION GREENHOUSE

Most types of plant material can be propagated without the use of a greenhouse but a good greenhouse makes the job much easier, quicker and cheaper. For a propagating greenhouse, I recommend fibreglass as the preferred covering. Double skinned poly-houses are quite effective for climate control, however, they have the disadvantage of screening out the ultraviolet light. Plants grown in a polyethylene house will burn badly when put out into bright sunlight, therefore, careful attention must be paid to hardening-off the plant material before outplanting.

Plants can be moved directly from a fibreglass house with little problem.

The heating system should be designed to maintain a minimum temperature of 5°C and, depending upon the location, a combination of shade cloth and fans, or manually opened ventilators, will prevent overheating during summer. The propagating bench itself should have metal supports. We use 1-1/2 inch galvanized pipe for the legs and 1-1/2 inch x 1/8 inch angle iron for the horizontal supports. For bench sides we use copper napthanate treated 2 inch x 4 inch on edge, allowing an inside width of 42-1/2 inches. This allows for the easy placement of two standard flats of 20-1/4 inch length on the bench.

Asbestos cement sheets make the best base for the propagating bed. Adequate drainage is provided by 1/4 inch holes drilled at about 1 foot intervals. Bottom heat for the bed can be provided either by hot water pipes with a thermostatically controlled circulating pump, or more simply, by an electric soil heating cable. If cable is used, provide 10 watts per square foot of bench. The cables or pipe should be covered with at least 1/2 inch of pea gravel to ensure good drainage and heat distribution.

An efficient, controllable mist system is essential. Refinements such as high intensity lighting and CO_2 injection are expensive and not really essential. A simple, economical, and effective mist system consists of a single line of 1/2 inch PVC pipe suspended 2 feet above the bench with FLORA-MIST wire shield propagating nozzles at a 3 foot spacing. The saddle-fitting nozzles are installed by drilling a hole in the PVC pipe and gluing the saddle in place. (PVC sawdust or drill shavings must be thoroughly cleaned from the pipe before nozzle installation, otherwise troublesome clogging will occur.) The mist is controlled by a 1/2 inch solenoid valve and a time clock or other sensing device. We prefer a 12 minute clock with 12 second intervals because it is simple and more fool-proof. Twenty to forty pounds psi is adequate for the water supply and, even with a very good quality water supply, a 5 gallon per minute replaceable screen filter should be installed in the line. A 25 micron screen is recommended.

A north-facing frame with bottom heat and fibreglass cover is a very useful addition to the greenhouse.

PROPAGATION METHODS

If you plan on propagating a fairly broad range of plant material, it will probably be necessary to use all three major propagating methods: seed, hardwood cuttings and softwood cuttings. The propagating bench can be used for both hardwood and softwood cuttings. Seedlings are generally grown in trays or flats placed directly on the floor of the greenhouse.

SEED

Unfortunately, the seed of many species is very difficult to collect and germinate. Seed of coniferous species should be collected as soon as the cones are mature and should be stored in open-weave bags with good air circulation until they can be processed. As rather elaborate facilities are necessary for cone handling, the cones should be shipped to a commercial extractory for processing and seed cleaning. The seed can then be stored in plastic bags at -2°C until required for stratification and sowing. The best single source of information regarding seed collection, storage, processing and germination is "Seeds of Woody Plants in the U.S.A.", Agricultural Handbook #450, catalogue #0100-02902 from Superintendent of Documents, Washington, D.C. 20402.

Container-grown seedlings usually establish much more easily than bare-root material. There are many different container systems in use for producing conifer seedlings. Most systems utilize pH corrected peat or peat vermiculite mixes as the growing medium. Most very large-scale operations provide nutrients with the irrigation water. An alternative particularly handy for a smaller operation is the incorporation of slow release fertilizers into the potting medium. We use both paperpots and Spencer Lemaire containers and a growing medium made up of straight sphagnum peat (preferably not too finely ground), with the following additions per cubic yard of material: 2 pounds of dolomitic limestone, 65 mesh; 2-1/2 pounds of Mag-Amp 7-40-6; 2 pounds of osmocote 18-6-12; 2 pounds of superphosphate 0-19-0; 2 pounds of gypsum; and 1-1/2 ounces of minor element mix.

Conifers are directly seeded into the pots using a vacuum operated mechanical seeder, then a light covering of medium-grade perlite is applied to cover the seed. The perlite retains moisture around the germinating seed, reflects bright sunlight, and prevents overheating. We normally do not stratify white spruce, lodgepole pine, jack pine or ponderosa pine. Douglas fir, both coast and interior varieties, is soaked overnight and stored damp in plastic bags at ±0°C for 30 days. Hemlock also responds to stratification; but with this species, there appears to be variable response depending on the seedlot. The seed is air-dried after stratification and then immediately sown.

Maintaining uniform moisture during the germination period is most important. After the initial watering, seed trays can be covered with polyethylene film but great care must be taken to see that the film is removed at the very first signs of germination.

Yellow cedar is not seeded directly. With a six month stratification period, this species germinates very erratically and over a long period. Normal procedure is to broadcast the seed in flats and to transplant the young seedlings to pots as they germinate.

Aspen is an important species and, unfortunately, one which is rather difficult to propagate. Hardwood cuttings will not root at all. Softwood cuttings produce a very low percentage of rooted cuttings. Root piece cuttings are reasonably successful but collecting aspen roots is rather expensive. We have not grown aspen from seed, for in the past several years there has been almost no seed available in the areas where we have been collecting. However, in the past, we have successfully collected seed for European customers who reported good results. The seed must be kept cool and handled very quickly; sowing must be done as soon as possible after collection.

Birch generally germinates well from seed which is collected in the fall and stored dry without stratification. Because of the lightness of the seed and its variability in germination, it is normally necessary to seed birch in flats and then transplant. Seed is broadcast without covering.

Alder (Alnus crispa and Alnus sinuata) can be broadcast directly into the containers as there is usually no objection to having multiple seedlings in a single container. As with birch, the alder seed is not covered.

Shrubby species which can be propagated from seed include: Saskatoon berry, buffalo berry and wild rose. Snow berry seeds prolifically but its germination seems to be completely unpredictable. Both buffalo berry and rose have hard seed coats and embryo dormancy. Although acid treatment has been used successfully to shorten the stratification period to one season for rose, our experience indicates that it is better to collect ahead of time and wait for the second-year germination. We get the best results by sowing the seed in sand flats and sitting them outside under the influence of fluctuating temperatures and the leaching action of rain. The sand flats must be well screened, otherwise birds and mice will eat most of the seed.

Some species require an after-ripening period. If seed is cleaned and then put immediately into cold storage, it will not respond to the normal stratification treatment. Pin cherry, choke cherry, Saskatoon berry and kinnikinick are in this category. Seeds of these species should be given a warm stratification of 30 to 60 days immediately following extraction. We have found the easiest method of doing this is to mix the seed with sand, place the seeded flats on the propagating bench, and bottom heat at 20°C. After this treatment a 90-day cold stratification is required.

HARDWOOD CUTTINGS

Species which can be propagated successfully from hardwood cuttings include poplar, willow, red twigged dogwood, shrubby cinquefoil and snow berry. Poplar and willow cuttings should be taken while still completely dormant, packed in plastic bags with damp peat moss and stored at 0°C. After the cuttings have calloused, they can be placed directly into the planting area or rooted in the greenhouse. The percentage of take will be much higher under greenhouse conditions.

The normal procedure for making poplar and willow hardwood cuttings is to make a 45° angle cut directly below the bud at the base of the cutting and a straight 90° cut just above the top bud of the three bud cutting. Red twigged dogwood cuttings should be prepared in the same way as poplar and willow. However, they should be propagated in flats of either sand or a sand/perlite mixture and given bottom heat. The greenhouse temperature should be kept as cool as possible during the rooting period to prevent premature and excessive top growth. In areas where greenhouse temperatures are warm, we have found that a north-facing, cable heated frame is very effective.

Dogwood cuttings should have a 1 inch basal wound and a #3 rooting powder mix (0.8% indole-butyric acid). Shrubby cinquefoil propagates quite easily using the same method as for dogwood. However, the cuttings used are quite small - normally about a 3 inch long cutting with the branchlets stripped from the lower half. Snow berry cuttings should be made only from good vigorous growth and should be 4-5 inches in length with the bottom 2 inches of the cutting cleaned off. Hardwood cuttings should always be made from vigorous healthy wood, a condition difficult to obtain with cuttings taken in the wild.

If cutting beds can be set up at the nursery where the mother plants can be fertilized and watered, the quality of cutting wood will be much better and rooting percentages will be much higher. We normally get about 70% rooting from collected dogwood cuttings and at least 90% from nursery grown material. With thin twiggy species such as cinquefoil and snow berry, the difference is even greater.

SOFTWOOD CUTTINGS

Species which are difficult or impossible to root from hardwood cuttings will very often root quite well from softwood cuttings taken during the summer. Dogwood, willow, honeysuckle and high and low bush cranberry are examples of species which root very quickly and easily from softwood cuttings. The initial collecting and handling of the cuttings prior to placement in the growing medium is critical. Preferably, cuttings should be taken only during the early morning before the heat of day and should be kept moist to prevent wilting. If possible, the cuttings should be placed in the flats and under the mist within 2 or 3 hours of picking. If this is not possible, they should be wrapped in damp sacking and kept cool in styrofoam containers. For most species, a softwood cutting should include a partially unfolded pair of tip leaves and one pair of fully developed leaves. The basal pair of leaves on the cutting are removed and the cutting trimmed just below the basal bud. Many species will root quite satisfactorily without the use of hormone powder; however, hormones speed up the rooting and usually result in denser rooting, which makes for easier transplanting. We use a #1 hormone powder for easy rooting material such as willow, #2 powder for most other soft cuttings, and the #3 powder only for fairly difficult rooting species.

Careful management of the cuttings to avoid wilt is critical for the first few days. This means that mist intervals should be short. On the other hand, continuous heavy misting for too long a period will result in reduced rooting. Generally, after the first three days, the mist intervals should be gradually increased, always ensuring the cuttings do not wilt. The rooting medium we use is concrete sand which is fairly coarse; masonry sand is too fine. The sand must be clean and any silt or clay should be washed out. We usually mix about 1/3 medium grade perlite with the sand to improve aeration and reduce the mix weight; it is also easier to work with. The addition of 25% peat to the rooting mix is a help with blueberry, huckleberry and buffalo berry.

There is a greater advantage in using nursery grown wood for softwood cuttings than for hardwood cuttings. If softwood cuttings are taken from mother plants which, themselves, are from collected cuttings grown for several years in the nursery, the new cuttings can be picked, trimmed, and placed under mist within an hour or less. Good quality softwood cuttings handled this way have the best rooting results.

Another type of cutting, root piece, is adaptable to some species and works well for aspen, rose, and raspberry. Root pieces are cut in 2-inch lengths and inserted in flats with the top of the cutting barely above the surface. The flats should have bottom heat but should not be pre-misted.

In summary, there is no mystery in the successful propagation of native woody species. The basis of a flourishing propagation program can be summarized: careful attention to water, heat and ventilation.

DISCUSSION RELATED TO D. CHRISTIE'S PAPER

Frank Pells - Brenda Mines Ltd.: Is the book you recommended from Washington much superior to the one by the B.C. Forest Service?

Answer: Yes. Although the B.C. Forest Service book is good, the Washington publication includes information about a lot more species.

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